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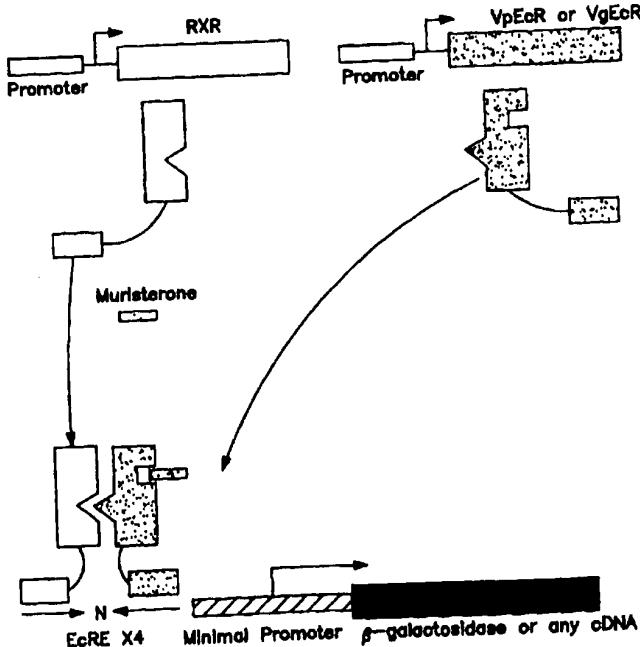
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(54) Title: HORMONE-MEDIATED METHODS FOR MODULATING EXPRESSION OF EXOGENOUS GENES IN MAMMALIAN SYSTEMS, AND PRODUCTS RELATED THERETO

(57) Abstract

In accordance with the present invention, there are provided various methods for modulating the expression of an exogenous gene in a mammalian subject employing modified ecdysone receptors. Also provided are modified ecdysone receptors, as well as homomeric and heterodimeric receptors containing same, nucleic acids encoding invention modified ecdysone receptors, modified ecdysone response elements, gene transfer vectors, recombinant cells, and transgenic animals containing nucleic acids encoding invention modified ecdysone receptor.



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Hormone-Mediated Methods For Modulating Expression Of  
Exogenous Genes In Mammalian Systems, and Products  
Related Thereto

FIELD OF THE INVENTION

The present invention relates to methods in the field of recombinant DNA technology, and products related thereto. More particularly, the invention relates to 5 methods and products for modulating the expression of exogenous genes in mammalian systems.

BACKGROUND OF THE INVENTION

The steroid/thyroid hormone receptors comprise a superfamily of ligand-dependent transcription factors that 10 play a crucial role in mediating changes in cell fate and function (Evans, R.M., Science 240:889-895 (1988)). The receptors transduce extracellular hormonal signals to target genes that contain specific enhancer sequences referred to as hormone response elements (HREs) Evans, 15 (1988); Green and Chambon, Trends Genet. 4:309-314 (1988); Yamamoto, K.R., Annu. Rev. Genet. 19:209-252 (1985)). Each receptor recognizes its own HRE, assuring that a distinct response is triggered by each hormonal signal. Together 20 the collection of related transcription factors and their cognate response elements provides a unique opportunity to control gene expression.

The DNA binding domain of each member of the steroid/thyroid superfamily of receptors has 66-68 amino acids. Twenty of these, including nine cysteines, are 25 conserved throughout the family. The modular structure of members of this receptor superfamily allows the exchange of homologous domains between receptors to create functional chimeras. This strategy was used to demonstrate that the DNA binding domain is solely responsible for the specific 30 recognition of the HRE in vivo (Green and Chambon, Nature

325:75-78 (1987); Giguère et al., Nature 330:624-629 (1987); Petkovich et al., Nature 330:444-450 (1987); Kumar et al., Cell 51:941-951 (1987); Umesono et al., Nature 336:262-265 (1988); Thompson and Evans, Proc. Natl. Acad. Sci. U.S.A. 86:3494-3498 (1989) and in vitro (Kumar and Chambon, Cell 55:145-156 (1988)). By analogy with the proposed structure for Xenopus transcription factor IIIA (Miller et al., EMBO J. 4:1609-1614 (1985)), the invariant cysteines are thought to form two "zinc fingers" that mediate the DNA binding function (Hollenberg and Evans, Cell 55:899-906 (1988)). Involvement of these cysteines in Zn(II) coordination is supported by extended X-ray absorption fine structure (Freedman et al., Nature 334:543-546 (1988)), and DNA binding by point mutagenesis experiments (Hollenberg and Evans, (1988)); Severne et al., EMBO J. 7:2503-2508 (1988)).

The HREs are in fact structurally related but functionally distinct. The glucocorticoid receptor response element (GRE), estrogen receptor response element (ERE), and thyroid hormone receptor response element (TRE) have been characterized in detail. These particular response elements have been found to have a palindromic pair of hexameric "half-sites" (Evans, (1988); Green and Chambon, (1988)). With optimized pseudo- or consensus response elements, only two nucleotides per half-site differ between GRE and ERE (Klock et al., Nature 329:734-736 (1987)). On the other hand, EREs and TREs have identical half-sites but the number of nucleotide spacers between the two half sites is different (Glass et al., Cell 54:313-323 (1988)).

In contrast to response elements having the palindromic sequence motif, the following hormone receptors typically recognize response elements having two half-sites in a direct-repeat (DR) sequence motif: RXR, RAR, COUP-TF, PPAR, and the like (see, e.g., Mangelsdorf et al., The

Retinoids: Biology, Chemistry, and Medicine, 2nd Edition, Raven Press, Ltd., New York, 1994, Chapter 8). Thus at least three distinct means are used to achieve HRE diversity: 1) binding site specificity for a particular 5 half-site; 2) nucleotide spacing between the two half-sites; and 3) the orientation of the half-sites to one another.

In insect systems, a pulse of the steroid hormone ecdysone triggers metamorphosis in Drosophila melanogaster 10 showing genomic effects, such as chromosomal puffing, within minutes of hormone addition. Mediating this response in insects is the functional ecdysone receptor, a heterodimer of the ecdysone receptor (EcR) and the product of the ultraspiracle gene (USP) (Yao et al. (1993) Nature 15 366, 476-479; and Yao et al. (1992) Cell 71, 63-72). Responsiveness to an insect ecdysteroid can be recreated in cultured mammalian cells by co-transfection of EcR, USP, an ecdysone responsive reporter, and treatment with ecdysone or the synthetic analog muristerone A.

20 In the field of genetic engineering, precise control of gene expression is an invaluable tool in studying, manipulating and controlling development and other physiological processes. For example applications for regulated gene expression in mammalian systems include 25 inducible gene targeting, overexpression of toxic and teratogenic genes, anti-sense RNA expression, and gene therapy (Jaenisch, R. (1988) Science 240, 1468-1474). For cultured cells, glucocorticoids and other steroids have been used to induce the expression of a desired gene.

30 As another means for controlling gene expression in a mammalian system, an inducible tetracycline regulated system has been devised and utilized in transgenic mice, whereby gene activity is induced in the absence of the antibiotic and repressed in its presence (see, e.g., Gossen

et al. (1992) Proc. Natl. Acad. Sci. **89**, 5547-5551; Gossen et al. (1993) TIBS **18**, 471-475; Furth et al. (1994) Proc. Natl. Acad. Sci. **91**, 9302-9306; and Shockett et al. (1995) Proc. Natl. Acad. Sci. **92**, 6522-6526). However, 5 disadvantages of this system include the continuous treatment of tetracycline to repress expression and the slow clearance of antibiotic from bone which interferes with quick and precise induction. While this system has been improved by the recent identification of a mutant 10 tetracycline repressor which acts conversely as an inducible activator, the pharmacokinetics of tetracycline may hinder its use during development when a precise and efficient "on-off" switch is essential (Gossen et al. (1995) Science **268**, 1766-1769).

15 Accordingly, there is a need in the art for improved methods to precisely modulate the expression of exogenous genes in mammalian subjects.

#### BRIEF DESCRIPTION OF THE INVENTION

In accordance with the present invention, there 20 are provided various methods for modulating the expression of an exogenous gene in a mammalian subject. The invention method is useful in a wide variety of applications where inducible in vivo expression of an exogenous gene is desired, such as in vivo therapeutic methods for delivering 25 recombinant proteins into a variety of cells within a patient.

Unlike prior art tetracycline based strategies, transferring ecdysone responsiveness to mammalian cells takes advantage of a naturally evolved steroid inducible 30 system. Advantages of ecdysteroid use include the lipophilic nature of the compounds (which provides efficient penetrance thereof into all tissues, including the brain), short half-lives (which allow for precise and

potent inductions), and favorable pharmacokinetics that prevent storage and expedite clearance.

In accordance with another embodiment of the present invention, there are provided modified ecdysone receptors, which can be in the form of homodimeric species or heterodimeric species comprising at least one silent partner of the steroid/thyroid superfamily of receptors, along with an invention modified ecdysone receptor. Invention modified ecdysone receptors are useful, for example, in methods for modulating expression of an exogenous gene in a mammalian subject.

In accordance with additional embodiments of the present invention, there are provided nucleic acids encoding invention modified ecdysone receptors, modified ecdysone receptor response elements, gene transfer vectors, recombinant cells, and transgenic animals containing nucleic acid encoding invention modified ecdysone receptor.

#### BRIEF DESCRIPTION OF THE FIGURES

Figures 1A - 1D show the optimization of ecdysone responsiveness using various combinations of USP or RXR with different modified EcRs. In Figure 1A, the numerical values on both sides of the figure are on the same scale, with the GEcR/RXR value repeated for clarity. Darkened and stripped bars represent reporter activity with no hormone or 1 $\mu$ M muristerone A, respectively.

Figure 1B shows FXR and VpEcR activity on ecdysone response element (EcRE) and a hybrid ecdysone/glucocorticoid response element (E/GRE) responsive reporters. VpEcR, VgEcR, and control transfection without receptors were treated with 1 $\mu$ M muristerone. FXR transfections were treated with 50 $\mu$ M Juvenile Hormone III (Sigma). Darkened and stripped bars represent reporter

activity with no hormone or 1 $\mu$ M muristerone A/50 $\mu$ M Juvenile Hormone III, respectively.

Figure 1C shows that E/GRE and GRE are non-overlapping response elements. Darkened and stripped 5 bars represent reporter activity with no hormone or 1 $\mu$ M muristerone A/1 $\mu$ M dexamethasone, respectively.

Figure 1D shows a schematic diagram of modified ecdysone receptors. GEcR is a chimeric receptor containing the N-terminal transactivation domain of GR and the DNA-10 and ligand-binding domains of EcR. VpEcR is an N-terminal truncation of EcR fused to the activation domain of Vp16. VgEcR is identical to VpEcR except for the following point mutations in the P box of the DNA binding domain: E282G, G283S, and G286V. In the Figure, DBD=DNA binding domain 15 and LBD=ligand binding domain.

Figure 2 shows a schematic diagram of an invention ecdysone inducible gene expression system. After expression of RXR and a modified EcR, the two receptors can heterodimerize and transactivate the ecdysone response 20 element-containing promoter in the presence of hormone. The ecdysone response elements are placed upstream of a minimal promoter (i.e., an enhancerless promoter) which can drive the expression of any exogenous cDNA.

Figure 3A shows a dose-dependent activation of 25 N13 cells with muristerone. N13 cells were grown with varying concentrations of muristerone for 36 hours and then assayed for  $\beta$ -galactidase activity (open squares) by standard ONPG assay .. for luciferase activity (closed circles). Figure 3B shows the time-course of luciferase 30 activity of N13 cells treated with hormone. N13 cells were grown in separate wells in the presence of 1 $\mu$ M muristerone, harvested at varying times, and assayed for luciferase activity as described in Example 3.

Figure 4 shows muristerone activity in mice as described in Example 4.

DETAILED DESCRIPTION OF THE INVENTION

In accordance with the present invention, there  
5 are provided methods for modulating the expression of an exogenous gene in a mammalian subject containing:

- (i) a DNA construct comprising said exogenous gene under the control of an ecdysone response element; and
- 10 (ii) a modified ecdysone receptor which, in the presence of a ligand therefor, and optionally in the further presence of a receptor capable of acting as a silent partner therefor, binds to said ecdysone response element;

15 said method comprising administering to said subject an effective amount of a ligand for said modified ecdysone receptor; wherein said ligand is not normally present in the cells of said subject; and wherein said 20 ligand is not toxic to said subject.

Thus, in accordance with the present invention the insect molting hormone, ecdysone, is advantageously employed as a regulated inducer of gene expression in mammalian systems, i.e., background levels of expression 25 are substantially zero in the absence of conditions required for induction. It has been found that optimized promoters containing a novel modified ecdysone response element in conjunction with an invention modified ecdysone receptor (preferably having an altered DNA binding 30 specificity) provide an extremely powerful and specific inducible mammalian expression system. The low basal activity of the invention expression system is advantageously suitable for the expression of transcription factors and toxic genes. The excellent dose response and

induction rate characteristics of the invention inducible expression system allow for precise control of both the degree and duration of induction of a desired gene.

Since the invention method provides for regulated 5 gene expression by an exogenous non-mammalian inducer, it can be advantageously employed in a variety of in vivo and in vitro mammalian expression systems. For example, inducible expression of cre recombinase in transgenic mammals, in accordance with invention methods, would enable 10 those of skill in the art to accomplish temporally specific inducible gene targeting of the adult or the developing embryo (O'Gorman et al. (1991) Science 251, 1351-1355).

As employed herein, the terms "modulate" and "modulating" refer to the ability of a given 15 ligand/receptor complex to effect transactivation of transcription of an exogenous gene, relative to such ability of said receptor in the absence of ligand. The actual effect of complex formation on the transactivation activity of a receptor will vary depending on the specific 20 receptor species which are part of the ligand/receptor complex, and on the response element with which the ligand/receptor complex interacts.

As used herein, when referring to genes, the phrase "exogenous to said mammalian subject" or simply 25 "exogenous" refers to any gene wherein the gene product is not naturally expressed in the particular cell where expression is desired. For example, exogenous genes can be either natural or synthetic wild type genes and therapeutic genes, which are introduced into the subject in the form of 30 DNA or RNA. The gene of interest can be introduced into target cells (for in vitro applications), or the gene of interest can be introduced directly into a subject, or indirectly introduced by the transfer of transformed cells into a subject.

"Wild type" genes are those that are native to cells of a particular type. Such genes may be undesirably overexpressed, or may not be expressed in biologically significant levels. Thus, for example, while a synthetic 5 or natural gene coding for human insulin would be exogenous genetic material to a yeast cell (since yeast cells do not naturally contain insulin genes), a human insulin gene inserted into a human skin fibroblast cell would be a wild type gene with respect to that cell since human skin 10 fibroblasts contain genetic material encoding human insulin, although human skin fibroblasts do not express human insulin in biologically significant levels.

Wild type genes contemplated for use in the practice of the present invention include genes which 15 encode a gene product:

the substantial absence of which leads to the occurrence of a non-normal state in said subject; or  
20 a substantial excess of which leads to the occurrence of a non-normal state in said subject;  
and the like.

As employed herein, the phrase "therapeutic gene" refers to a gene which imparts a beneficial function to the host cell in which such gene is expressed. Therapeutic 25 genes are those that are not naturally found in host cells. For example, a synthetic or natural gene coding for wild type human insulin would be therapeutic when inserted into a skin fibroblast cell so as to be expressed in a human host, where the human host is not otherwise capable of 30 expressing functionally active human insulin in biologically significant levels. In accordance with the methods described herein, therapeutic genes are expressed at a level that provides a therapeutically effective amount of the corresponding therapeutic protein.

Therapeutic genes contemplated for use in the practice of the present invention include genes which encode a gene product:

5           which is toxic to the cells in which it is expressed; or

              which imparts a beneficial property to the host subject (e.g., disease resistance, etc); and the like.

Numerous genomic and cDNA nucleic acid sequences 10 coding for a variety of proteins are well known in the art. Exogenous genetic material useful in the practice of the present invention include genes that encode biologically active proteins of interest, such as, e.g., secretory proteins that can be released from said cell; enzymes that 15 can metabolize a substrate from a toxic substance to a non-toxic substance, or from an inactive substance to a useful substance; regulatory proteins; cell surface receptors; and the like. Useful genes include genes that encode blood clotting factors such as human factors VIII and IX; genes 20 that encode hormones such as insulin, parathyroid hormone, luteinizing hormone releasing factor (LHRH), alpha and beta seminal inhibins, and human growth hormone; genes that encode proteins such as enzymes, the absence of which leads to the occurrence of an abnormal state; genes encoding 25 cytokines or lymphokines such as interferons, granulocytic macrophage colony stimulating factor (GM-CSF), colony stimulating factor-1 (CSF-1), tumor necrosis factor (TNF), and erythropoietin (EPO); genes encoding inhibitor substances such as alpha,-antitrypsin; genes encoding 30 substances that function as drugs, e.g., genes encoding the diphtheria and cholera toxins; and the like.

Typically, nucleic acid sequence information for a desired protein can be located in one of many public access databases, e.g., GENBANK, EMBL, Swiss-Prot, and PIR, 35 or in many biology related journal publications. Thus,

those of skill in the art have access to nucleic acid sequence information for virtually all known genes. Those of skill in the art can either obtain the corresponding nucleic acid molecule directly from a public depository or 5 the institution that published the sequence. Optionally, once the nucleic acid sequence encoding a desired protein has been ascertained, the skilled artisan can employ routine methods, e.g., polymerase chain reaction (PCR) amplification, to isolate the desired nucleic acid molecule 10 from the appropriate nucleic acid library. Thus, all known nucleic acids encoding proteins of interest are available for use in the methods and products described herein.

As used herein, the terms "mammal" and "mammalian" refer to humans; domesticated animals, e.g., 15 rats, mice, rabbits, canines, felines, and the like; farm animals, e.g., chickens, bovine, porcine and ovine, and the like; and animals of zoological interest, e.g., monkeys and baboons, and the like.

Modified ecdysone receptors contemplated for use 20 in the practice of the present invention comprise:

an ecdysone ligand binding domain;  
a DNA-binding domain obtained from a DNA-  
binding protein; and  
25 an activation domain of a transcription  
factor,

wherein at least one of said DNA-binding  
domain or said activation domain is not obtained  
from a native ecdysone receptor,  
with the proviso that when said activation domain is  
30 derived from a glucocorticoid receptor, said DNA-binding  
domain is not derived from a glucocorticoid receptor or an  
E. coli LexA protein. In accordance with the present  
invention, modified ecdysone receptors function in  
expression systems, preferably mammalian, to transactivate

gene expression from transcription regulatory regions having ecdysone response elements.

Ecdysone ligand binding domains contemplated for use in the preparation of invention modified ecdysone receptors are typically derived from the carboxy-terminal portion of native ecdysone receptor and are able to bind ecdysteroids (Koelle et al., Cell, 67:59-77, 1991; and Christopherson et al., PNAS, USA, 89:6314-6318, 1992). Ecdysone ligand binding domains can be functionally located 5 in either orientation and at various positions within the modified ecdysone receptor of the invention. For example, the ecdysone ligand binding domain can be positioned at either the amino or carboxy terminus of the modified receptor, or therebetween. In a preferred embodiment of 10 the present invention, the ecdysone ligand binding domain is positioned at the carboxy terminus of the modified receptor, or therebetween. In a preferred embodiment of 15 the present invention, the ecdysone ligand binding domain is positioned at the carboxy terminus of the modified receptor (see Figure 1D).

DNA-binding domains contemplated for use in the preparation of invention modified ecdysone receptors are 20 typically obtained from DNA-binding proteins (e.g., transcription factors). The term "DNA-binding domain" is understood in the art to refer to an amino acid sequence that is able to bind to DNA. As used herein, the term "DNA-binding domain" encompasses a minimal peptide sequence 25 of a DNA-binding protein, up to the entire length of a DNA-binding protein, so long as the DNA-binding domain functions to associate with a particular response element.

Such DNA-binding domains are known to function heterologously in combination with other functional protein 30 domains by maintaining the ability to bind the natural DNA recognition sequence (see, e.g., Brent and Ptashne, 1985, Cell, 43:729-736). For example, hormone receptors are known to have interchangeable DNA-binding domains that function in chimeric proteins (see, e.g., U.S. Patent

4,981,784; and Evans, R., 1988, Science, 240:889-895). Thus, similar to the ligand binding domain of invention modified ecdysone receptor, the DNA-binding domain can be positioned at either the carboxy terminus or the amino 5 terminus, or the DNA-binding domain can be positioned between the ligand binding domain and the activation domain. In preferred embodiments of the present invention, the DNA-binding domain is positioned internally between the ligand binding domain and the activation domain.

10 "DNA-binding protein(s)" contemplated for use herein belong to the well-known class of proteins that are able to directly bind DNA and facilitate initiation or repression of transcription. Exemplary DNA-binding proteins contemplated for use herein include transcription 15 control proteins (e.g., transcription factors and the like; Conaway and Conaway, 1994, "Transcription Mechanisms and Regulation", Raven Press Series on Molecular and Cellular Biology, Vol. 3, Raven Press, Ltd., New York, NY).

Transcription factors contemplated for use herein 20 as a source of such DNA binding domains include, e.g., homeobox proteins, zinc finger proteins, hormone receptors, helix-turn-helix proteins, helix-loop-helix proteins, basic-Zip proteins (bZip),  $\beta$ -ribbon factors, and the like. See, for example, Harrison, S., "A Structural Taxonomy of 25 DNA-binding Domains," Nature, 353:715-719. Homeobox DNA-binding proteins suitable for use herein include, for example, HOX, STF-1 (Leonard et al., 1993, Mol. Endo., 7:1275-1283), Antp, Mat  $\alpha$ -2, INV, and the like. See, also, Scott et al. (1989), Biochem. Biophys. Acta, 989:25-48. It 30 has been found that a fragment of 76 amino acids (corresponding to amino acids 140-215 described in Leonard et al., 1993, Mol. Endo., 7:1275-1283) containing the STF-1 homeodomain binds DNA as tightly as wild-type STF-1. Suitable zinc finger DNA-binding proteins for use herein 35 include Zif268, GLI, XFin, and the like. See also, Klug

and Rhodes (1987), Trends Biochem. Sci., 12:464; Jacobs and Michaels (1990), New Biol., 2:583; and Jacobs (1992), EMBO J., 11:4507-4517.

Preferably, the DNA-binding domain used herein is obtained from a member of the steroid/thyroid superfamily of receptors. As used herein, the phrase "member(s) of the steroid/thyroid hormone superfamily of receptors" (also known as "nuclear receptors" or "intracellular receptors") refers to hormone binding proteins that operate as ligand-dependent transcription factors, including identified members of the steroid/thyroid superfamily of receptors for which specific ligands have not yet been identified (referred to hereinafter as "orphan receptors").

Exemplary members of the steroid/thyroid superfamily of receptors (including the various isoforms thereof) include steroid receptors such as glucocorticoid receptor (GR), mineralocorticoid receptor (MR), estrogen receptor (ER), progesterone receptor (PR), androgen receptor (AR), vitamin D<sub>3</sub> receptor (VDR), and the like; plus retinoid receptors, such as the various isoforms of retinoic acid receptor (e.g., RAR $\alpha$ , RAR $\beta$ , or RAR $\gamma$ ), the various isoforms of retinoid X receptor (e.g., RXR $\alpha$ , RXR $\beta$ , or RXR $\gamma$ ), and the like (see, e.g., U.S. Patents 4,981,784; 5,171,671; and 5,071,773); thyroid receptors (TR), such as TR $\alpha$ , TR $\beta$ , and the like; insect derived receptors such as the ecdysone receptor, and the like; as well as other gene products which, by their structure and properties, are considered to be members of the superfamily, as defined hereinabove, including the various isoforms thereof.

Examples of orphan receptors contemplated for use herein as a source of DNA binding domain include HNF4 [see, for example, Sladek et al., in Genes & Development 4: 2353-2365 (1990)], the COUP family of receptors [see, for example, Miyajima et al., in Nucleic Acids Research 16: 11057-11074 (1988), and Wang et al., in Nature 340: 163-166 (1989)].

COUP-like receptors and COUP homologs, such as those described by Mlodzik et al., in Cell 60: 211-224 (1990) and Ladias et al., in Science 251: 561-565 (1991), various isoforms of peroxisome proliferator-activated receptors 5 (PPARs; see, for example, Issemann and Green, supra), the insect derived knirps and knirps-related receptors, and the like.

The DNA-binding domains of all members of the steroid/thyroid superfamily of receptors are related, 10 consisting of 66-68 amino acid residues, and possessing about 20 invariant amino acid residues, including nine cysteines. A member of the superfamily can be characterized as a protein which contains these 20 invariant amino acid residues. The highly conserved amino 15 acids of the DNA-binding domain of members of the superfamily are as follows:

Cys - X - X - Cys - X - X - Asp\* - X -  
Ala\* - X - Gly\* - X - Tyr\* - X - X -  
X - X - Cys - X - X - Cys - Lys\* - X -  
20 Phe - Phe - X - Arg\* - X - X - X - X -  
X - X - X - X - X - (X - X -) Cys - X -  
X - X - X - X - (X - X - X -) Cys - X -  
X - X - Lys - X - X - Arg - X - X -  
Cys - X - X - Cys - Arg\* - X - X -  
25 Lys\* - Cys - X - X - X - Gly\* - Met  
(SEQ ID NO:1);

wherein X designates non-conserved amino acids within the DNA-binding domain; an asterisk denotes the amino acid residues which are almost universally conserved, but for 30 which variations have been found in some identified hormone receptors; and the residues enclosed in parenthesis are optional residues (thus, the DNA-binding domain is a minimum of 66 amino acids in length, but can contain several additional residues).

Modification of existing DNA-binding domains to recognize new target recognition sequences is also contemplated herein. For example, in accordance with the present invention, it has been found that the modification 5 of the "P-box" sequence of DNA-binding domains of members of the steroid/thyroid superfamily of receptors offers unique advantages not present in other chimeric hormone receptors. For example, the modification of a P-box amino acid sequence to preferentially bind to a different hormone 10 response element half-site than the naturally occurring P-box amino acid sequence can reduce undesired background levels of gene expression. Thus, invention receptors and methods provide the advantage of increasing the selectivity of exogenous gene expression in a particular subject.

15 As used herein, the phrase "P-box amino acid sequence" refers to the proximal element region in a DNA-binding domain of a hormone receptor that typically occurs at the junction of the first zinc finger and the linker region, e.g., at about amino acids 19-23 of the DNA-binding 20 domain (i.e., amino acids 19-23 of SEQ ID NO:1; see, e.g., Umesono et al. (1989), Cell, 57:1139-1146, Figure 2). Umesono et al. (1989), supra, in Table 1, describe various naturally occurring P-box amino acid sequences for a variety of hormone receptor DNA-binding domains.

25 In one embodiment of the present invention, the P-box sequence of a hormone receptor DNA-binding domain is modified to have a P-box amino acid sequence that differs from the naturally occurring P-box amino acid sequence. In a preferred embodiment of the present invention, the 30 modified P-box amino acid sequence differs from the naturally occurring P-box amino acid sequence by 3 amino acids.

Preferably, the P-box amino acid sequence is modified so that only the half-site nucleotide sequence

recognized by the DNA-binding domain is changed while not altering the spacing between the two half-sites recognized by the DNA-binding domain. For example, when the DNA-binding domain of the ecdysone receptor is employed in an 5 invention modified ecdysone receptor, the P-box can be modified from the amino acid sequence EGCKG (SEQ ID NO:2; which recognizes the half-site -AGGTCA-) to the amino acid sequence GSCKV (SEQ ID NO:3; which recognizes the half-site sequence -AGAACCA-). In a presently preferred embodiment, 10 when the DNA-binding domain of invention modified ecdysone receptor is derived from ecdysone receptor, the P-box amino acid sequence is modified to GSCKV (SEQ ID NO:3).

It has also been found that in vitro evolution methods can be applied to modify and improve existing DNA- 15 binding domains (see, e.g., Devlin et al., 1990, Science, 249:404-406; and Scott and Smith, 1990, Science, 249:386-390).

Activation domains contemplated for use in the preparation of invention modified ecdysone receptor are 20 typically derived from transcription factors and comprise a contiguous sequence of amino acids that functions to activate gene expression when associated with a suitable DNA-binding domain and a suitable ligand binding domain. As with the ligand and DNA-binding domains employed for the 25 preparation of invention modified ecdysone receptors, the activation domain can be positioned at the carboxy terminus, the amino terminus or between the ligand binding domain and the DNA binding domain. In preferred embodiments of present invention, the activation domain is 30 positioned at the amino terminus of the modified ecdysone receptor.

Suitable activation domains can be obtained from a variety of sources, e.g., from the N-terminal region of a member of the steroid/thyroid superfamily of receptors,

from a transcription factor activation domain, such as, for example, VP16 or GAL4 activation domains, and the like. The presently most preferred activation domain contemplated for use in the practice of the present invention is 5 obtained from the N-terminal region of the VP16 protein.

The presently most preferred modified ecdysone receptors contemplated for use herein are VgEcR (SEQ ID NO:5), VpEcR (SEQ ID NO:7) or GEcR (SEQ ID NO:9), with VgEcR (SEQ ID NO:5) being especially preferred. The 10 preparation of these modified ecdysone receptors is set forth hereinafter in Example 1.

Invention modified ecdysone receptor proteins can be produced by expressing nucleic acid constructs encoding the chimeric proteins in suitable host cells as described 15 in Example 1. Recombinant methods of producing desired proteins by introducing an expression construct into appropriate host cells are well-known in the art. Modified ecdysone receptors of the invention can be introduced into a particular subject by direct introduction of the proteins 20 themselves, by introducing DNA construct(s) encoding the receptor into the subject, or into cells obtained from the subject (wherein the cells are transformed and subsequently returned to the subject).

In a preferred embodiment, invention modified 25 ecdysone receptors are expressed under the control of a tissue specific promoter. As readily understood by those of skill in the art, the term "tissue specific" refers to the substantially exclusive initiation of transcription in the tissue from which a particular promoter drives 30 expression of a given gene.

In accordance with one aspect of the present invention, invention modified ecdysone receptors are present in the form of heterodimeric species comprising an

invention modified ecdysone receptor and at least one silent partner of the steroid/thyroid superfamily of receptors. Preferably, the silent partner is a mammalian-derived receptor, with RXR being especially preferred.

5           Silent partners contemplated herein are members of the steroid/thyroid superfamily of receptors which are capable of forming heterodimeric species with the invention modified ecdysone receptor, wherein the silent partner does not directly participate in binding ligand (i.e., only the  
10 modified ecdysone receptor co-partner of the heterodimer binds ligand). The silent partner can either be endogenous to the cells of the subject or can be provided to the subject by introducing DNA construct(s) encoding receptor into the subject. A preferred silent partner for use  
15 herein is RXR. In a particular embodiment of the invention methods, exogenous RXR is provided to said mammalian subject.

The formation of heterodimeric receptor(s) can modulate the ability of member(s) of the steroid/thyroid  
20 superfamily of receptors to trans-activate transcription of genes maintained under expression control in the presence of ligand for said receptor. For example, formation of a heterodimer of the modified ecdysone receptor with another mammalian hormone receptor promotes the ability of the  
25 modified ecdysone receptor to induce trans-activation activity in the presence of an ecdysone response element.

In accordance with another aspect of the present invention, invention modified ecdysone receptors are present in the form of homodimeric species comprising a  
30 plurality (i.e., at least two) invention modified ecdysone receptors.

Ligands contemplated for use herein are compounds which, inside a cell, bind to invention modified ecdysone

receptors, thereby creating a ligand/receptor complex, which in turn can bind to an appropriate response element. The terms "ecdysone" and "ecdysteroid" as interchangeably used herein, are employed herein in the generic sense (in accordance with common usage in the art), referring to a family of ligands with the appropriate binding and transactivation activity (see, for example, Cherbas et al., in Biosynthesis, metabolism and mode of action of invertebrate hormones (ed. J. Hoffmann and M. Porchet), p. 305-322; Springer-Verlag, Berlin). An ecdysone, therefore, is a compound which acts to modulate gene transcription for a gene maintained under the control of an ecdysone response element.

20-Hydroxy-ecdysone (also known as  $\beta$ -ecdysone) is the major naturally occurring ecdysone. Unsubstituted ecdysone (also known as  $\alpha$ -ecdysone) is converted in peripheral tissues to  $\beta$ -ecdysone. Analogs of the naturally occurring ecdysones are also contemplated within the scope of the present invention. Examples of such analogs, commonly referred to as ecdysteroids, include ponasterone A, 26-iodoponasterone A, muristerone A, inokosterone, 26-mesylinokosterone, and the like. Since it has been previously reported that the above-described ecdysones are neither toxic, teratogenic, nor known to affect mammalian physiology, they are ideal candidates for use as inducers in cultured cells and transgenic mammals according to the invention methods.

Ligands contemplated for use in the practice of the present invention are characterized as not normally being present in the cell of the subject, meaning that the ligand is exogenous to the subject. Ecdysteroids, for example, are not naturally present in mammalian systems. Thus, in accordance with the invention method, unless and until an ecdysteroid is administered to the subject, substantially no expression of the desired gene occurs.

An effective amount of ligand contemplated for use in the practice of the present invention is the amount of ligand (i.e., ecdysteroid) required to achieve the desired level of gene expression product. Ligand can be 5 administered in a variety of ways, as are well-known in the art. For example, such ligands can be administered topically, orally, intravenously, intraperitoneally, intravascularly, and the like.

Ecdysone response elements contemplated for use 10 in the practice of the present invention (relating to modulation of the expression of exogenous genes in a subject) include native, as well as modified ecdysone response elements. Since invention modified ecdysone receptors can function as either homodimers or as 15 heterodimers (with a silent partner therefor), any response element that is responsive to an invention modified ecdysone receptor, in the form of a homodimer or heterodimer, is contemplated for use in the invention methods described herein. In a preferred embodiment of the 20 invention, invention modified ecdysone response elements are engineered so as to no longer be capable of binding to a farnesoid hormone receptor (since the mammalian farnesoid hormone receptor is able to bind to native ecdysone receptor response element). Invention modified ecdysone 25 response elements provide low background expression levels of the exogenous gene and increase the selectivity of the gene expression system when used in mammalian systems.

Ecdysone response elements contemplated for use herein are short *cis*-acting sequences (i.e., having about 30 12-20 bp) that are required for activation of transcription in response to a suitable ligand, such as ecdysone or muristerone A, associated with a particular hormone receptor. The association of these response elements with otherwise ecdysone-nonresponsive regulatory sequences 35 causes such regulatory sequences to become ecdysone

responsive. Ecdysone response element sequences function in a position- and orientation-independent fashion.

The native ecdysone response element has been previously described, see, e.g., Yao et al., *Cell*, 71:63-5 72, 1992. Modified ecdysone response elements according to present invention comprise two half-sites (in either direct repeat or inverted repeat orientation to one another), separated by a spacer of 0-5 nucleotides. As used herein, the term "half-site" refers to a contiguous 6 nucleotide 10 sequence that is bound by a particular member of the steroid/thyroid superfamily of receptors. Each half-site is typically separated by a spacer of 0 up to about 5 nucleotides. Typically, two half-sites with a corresponding spacer make up a hormone response element. 15 Hormone response elements can be incorporated in multiple copies into various transcription regulatory regions.

Preferred modified ecdysone response elements according to the invention comprise, in any order, a first half-site and a second half-site separated by a spacer of 20 0-5 nucleotides;

wherein the first and second half-sites are inverted with respect to each other;  
wherein said first half-site has the sequence:

25 -RGBNNM-,  
(or complements thereof) wherein  
each R is independently selected from A or G;  
each B is independently selected from G, C, or T;  
each N is independently selected from A, T, C, or  
30 G; and  
each M is independently selected from A or C;  
with the proviso that at least 4 nucleotides of each  
-RGBNNM- group of nucleotides are identical with the  
nucleotides at comparable positions of the sequence  
35 -AGGTCA-; and

said second half-site is obtained from a glucocorticoid receptor subfamily response element.

The complement to the -RGBNNM- sequence set forth above is:

5 -YCVNNK-,

wherein

each Y is independently selected from T or C;  
each V is independently selected from C, G, or A;  
each N is independently selected from A, T, C, or  
10 G; and  
each K is independently selected from T or G.

Exemplary first half-sites having the -RGBNNM- motif for use in the invention modified ecdysone response element include, for example, half-sites selected from  
15 -AGGGCA-, -AGTTCA-, -AGGTAA-, -AGGTCA-, -GGTTCA-,  
-GGGTTA-, -GGGTGA-, -AGGTGA-, or -GGGTCA-. A particularly preferred first half-site is -AGTGCA-.

Glucocorticoid receptor subfamily response elements contemplated for use in the practice of the present invention are response elements having half-sites that are typically bound by glucocorticoid, mineralocorticoid, progesterone or androgen receptors. Suitable half-sites from glucocorticoid receptor subfamily response elements can be selected from the following  
25 sequence (in either orientation):

-RGNNCA-

(or complements thereof such as -YCNNGT-), wherein R, Y and N are as defined above. Exemplary half-sites having the -RGNNCA- motif for use in the invention modified ecdysone response element include -AGAACCA-, -GGAACCA-, -AGTTCA-,  
30 -AGGTCA-, -GGAACCA-, -GGTTCA-, -GGGTCA-, -GGGTCA-, -AGGTGA-, -GGGTCA-, and the like, as well as complements thereof. Particularly preferred half-sites having the

-RGNNCA- motif include -AGAACCA- and -GGAACA-, with -AGAACCA- being especially preferred.

When the above-described modified ecdysone response elements are employed to bind invention heterodimeric receptors, the second half-site is inverted with respect to the first half-site. For example, when describing a single-strand of an invention modified ecdysone response element in the 5'-3' direction, the following general motif can be employed:

10                   RGBNNM-(N)<sub>x</sub>-TGNNCY (SEQ ID NO:10),

where x is an integer of 0 up to about 5, with x = 1 being especially preferred. As an alternative orientation to the above described response element motif (SEQ ID NO:10), an invention response element can be described in the 5'-3' 15 direction as:

RGNNA-(N)<sub>x</sub>-KNVCY (SEQ ID NO:11),

where x is an integer of 0 up to about 5, with x = 1 being especially preferred.

In preferred embodiments of the present invention, the first half-site is obtained from an ecdysone response element and the second half-site is obtained from a hormone response element selected from a glucocorticoid response element, a mineralocorticoid response element, a progesterone response element or an androgen response element. In a particularly preferred embodiment of the present invention, the first half-site is obtained from an ecdysone response element and the second half-site is obtained from a glucocorticoid response element.

In a particularly preferred embodiment of the 30 invention modified ecdysone response element, the first

half-site is AGTGCA and said second half-site is TGTTCT. The presently most preferred modified-ecdysone response element for use in the invention methods is:

AGTGCA-N-TGTTCT (SEQ ID NO:12).

5 In another aspect of the invention, when modified ecdysone receptors of the invention exist as homodimers, response elements employed preferably have a direct repeat motif (instead of the above-described inverted repeat motif), as follows:

10 RGBNNM-(N)<sub>x'</sub>-RGBNNM (SEQ ID NO:13),

where R, B, N and M are as previously defined, and x' is an integer of 0 up to about 5, with x' = 3 being especially preferred.

Invention modified ecdysone response elements are  
15 characterized as having substantially no constitutive activity, which refers to the substantial absence of background levels of gene expression initiated by invention modified ecdysone response elements when introduced into mammalian expression systems. Since it has been found that  
20 mammalian farnesoid hormone receptors are able to bind to and transactivate gene expression from native ecdysone response elements, in certain embodiments of the present invention (e.g., where it is desired to avoid farnesoid-mediated background expression), modified ecdysone response  
25 elements are employed.

Presently preferred invention modified ecdysone response elements are further characterized as having substantially no binding affinity for farnesoid X receptor (FXR), i.e., invention response elements are incapable of  
30 binding FXR (which would thereby create undesired background levels of expression). Thus, presently

preferred invention modified ecdysone response elements preferably induce basal levels of expression of substantially zero.

Response elements employed in the practice of the present invention are operably linked to a suitable promoter for expression of exogenous gene product(s). As used herein, the term "promoter" refers to a specific nucleotide sequence recognized by RNA polymerase, the enzyme that initiates RNA synthesis. This sequence is the site at which transcription can be specifically initiated under proper conditions. When exogenous genes, operatively linked to a suitable promoter, are introduced into the cells of a suitable host, expression of the exogenous genes is controlled by the presence of ecdysteroid compounds, which are not normally present in the host cells.

In accordance with another embodiment of the present invention, there are provided methods of inducing the expression of an exogenous gene in a mammalian subject containing:

- (i) a DNA construct comprising an exogenous gene under the control of an ecdysone response element,
- (ii) DNA encoding a modified ecdysone receptor under the control of an inducible promoter; wherein said modified ecdysone receptor, in the presence of a ligand therefor, and optionally in the further presence of a receptor capable of acting as a silent partner therefor, binds to said ecdysone response element, and
- (iii) a ligand for said modified ecdysone receptor;

said method comprising subjecting said subject to conditions suitable to induce expression of said modified ecdysone receptor.

Inducible promoters contemplated for use in the practice of the present invention are transcription regulatory regions that do not function to transcribe mRNA unless inducing conditions are present. Examples of suitable inducible promoters include DNA sequences corresponding to: the E. coli lac operator responsive to IPTG (see Nakamura et al., Cell, 18:1109-1117, 1979); the metallothionein promoter metal-regulatory-elements responsive to heavy-metal (e.g. zinc) induction (see Evans et. al, U.S. Patent No. 4,870,009), the phage T7lac promoter responsive to IPTG (see Studier et al., Meth. Enzymol., 185: 60-89, 1990; and U.S. #4,952,496), the heat-shock promoter, and the like.

In accordance with another embodiment of the present invention, there are provided methods of inducing expression of an exogenous gene in a mammalian subject containing a DNA construct comprising said exogenous gene under the control of an ecdysone response element, said method comprising introducing into said subject:

a modified ecdysone receptor; and  
a ligand for said modified ecdysone  
receptor,

wherein said receptor, in combination with a ligand therefor, and optionally in the further presence of a receptor capable of acting as a silent partner therefor, binds to said ecdysone response element, activating transcription therefrom.

In accordance with another embodiment of the present invention, there are provided methods for the expression of recombinant products detrimental to a host organism, said method comprising:

transforming suitable host cells with:

- (i) a DNA construct encoding said recombinant product under the control of an ecdysone response element, and
- 5 (ii) DNA encoding a modified ecdysone receptor;

growing said host cells in suitable media; and inducing expression of said recombinant product by introducing into said host cells ligand(s) for said 10 modified ecdysone receptor, and optionally a receptor capable of acting as a silent partner for said modified ecdysone receptor.

Recombinant products detrimental to a host organism contemplated for expression in accordance with the 15 present invention include any gene product that functions to confer a toxic effect on the organism. For example, inducible expression of a toxin such as the diphtheroid toxin would allow for inducible tissue specific ablation (Ross et al. (1993) Genes and Development 7, 1318-1324). 20 Thus, the numerous gene products that are known to induce apoptosis in cells expressing such products are contemplated for use herein (see, e.g., Apoptosis. The Molecular Basis of Cell Death, Current Communications In Cell & Molecular Biology, Cold Spring Harbor Laboratory 25 Press, 1991).

Suitable media contemplated for use in the practice of the present invention include any growth and/or maintenance media, in the substantial absence of ligand(s) which, in combination with an invention modified ecdysone 30 receptor, is(are) capable of binding to an ecdysone response element.

In accordance with another embodiment of the present invention, there are provided nucleic acids encoding invention modified ecdysone receptors. Invention

nucleic acids can be incorporated into various expression vectors known to those of skill in the art. Preferred nucleic acids encoding modified ecdysone receptors are set forth in SEQ ID NOS:4, 6 and 8, with SEQ ID NO:4 being especially preferred.

In accordance with another embodiment of the present invention, there are provided gene transfer vectors useful for the introduction of invention constructs into suitable host cells. Such gene transfer vectors comprise 10 a transcription regulatory region having a minimal promoter (i.e., a promoter region that does not have an enhancer), and an invention modified ecdysone response element, wherein said regulatory region is operatively associated with DNA containing an exogenous gene, and wherein said 15 modified ecdysone response element is present in multiple copies. The number of copies of response elements can readily be varied by those of skill in the art. For example, transcription regulatory regions can contain from 1 up to about 50 copies of a particular response element, 20 preferably 2 up to about 25 copies, more preferably 3 up to about 10-15 copies, with about 4-6 copies being especially preferred.

Gene transfer vectors (also referred to as "expression vectors") contemplated for use herein are 25 recombinant nucleic acid molecules that are used to transport exogenous nucleic acid into cells for expression and/or replication thereof. Expression vectors may be either circular or linear, and are capable of incorporating a variety of nucleic acid constructs therein. Expression 30 vectors typically come in the form of a plasmid that, upon introduction into an appropriate host cell, results in expression of the inserted DNA.

As used herein, the phrase "transcription regulatory region" refers to the region of a gene or

expression construct that controls the initiation of mRNA transcription. Regulatory regions contemplated for use herein typically comprise at least a minimal promoter in combination with an ecdysone response element. A minimal 5 promoter, when combined with an enhancer region (e.g., a hormone response element), functions to initiate mRNA transcription in response to a ligand/receptor complex. However, transcription will not occur unless the required inducer (ligand) is present.

10 As used herein, the phrase "operatively associated with" refers to the functional relationship of DNA with regulatory and effector sequences of nucleotides, such as promoters, enhancers, transcriptional and translational stop sites, and other signal sequences. For 15 example, operative linkage of DNA to a promoter refers to the physical and functional relationship between the DNA and promoter such that the transcription of such DNA is initiated from the promoter by an RNA polymerase that specifically recognizes, binds to and transcribes the DNA.

20 Preferably, the transcription regulatory region further comprises a binding site for an ubiquitous transcription factor. Such a binding site is preferably positioned between the promoter and modified ecdysone response element of the invention. Suitable ubiquitous 25 transcription factors for use herein are well-known in the art and include, for example, Spl.

Expression vectors suitable for use in the practice of the present invention are well known to those of skill in the art and include those that are replicable 30 in eukaryotic cells and/or prokaryotic cells as well as those that remain episomal and those that integrate into the host cell genome. Expression vectors typically further contain other functionally important nucleic acid

sequences, such as expression constructs encoding antibiotic resistance proteins, and the like.

Exemplary eukaryotic expression vectors include eukaryotic constructs, such as the pSV-2 gpt system 5 (Mulligan et al., Nature, 1979, 277:108-114); pBlueSkript (Stratagene, La Jolla, CA), the expression cloning vector described by Genetics Institute (Science, 1985, 228:810-815), and the like. Each of these plasmid vectors are capable of promoting expression of the invention chimeric 10 protein of interest.

Promoters, depending upon the nature of the regulation, may be constitutively or inducibly regulated, or may be tissue-specific (e.g., expressed only in T-cells, endothelial cells, smooth muscle cells, and the like). 15 Exemplary promoters contemplated for use in the practice of the present invention include the SV40 early promoter, the cytomegalovirus (CMV) promoter, the mouse mammary tumor virus (MMTV) steroid-inducible promoter, Moloney murine leukemia virus (MMLV) promoter, elongation factor 1 $\alpha$  (EF1 $\alpha$ ) promoter, albumin promoter, APO A1 promoter, cyclic AMP dependent kinase II (CaMKII) promoter, keratin promoter, CD3 promoter, immunoglobulin light or heavy chain promoters, neurofilament promoter, neuron specific enolase promoter, L7 promoter, CD2 promoter, myosin light chain 20 promoter, HOX gene promoter, thymidine kinase (TK) promoter, RNA Pol II promoter, MYOD promoter, MYF5 promoter, phosphoglycerokinase (PGK) promoter, Stf1 promoter, Low Density Lipoprotein (LDL) promoter, and the like. 25

30 Suitable means for introducing (transducing) expression vectors containing invention nucleic acid constructs into host cells to produce transduced recombinant cells (i.e., cells containing recombinant heterologous nucleic acid) are well-known in the art (see,

for review, Friedmann, 1989, Science, 244:1275-1281; Mulligan, 1993, Science, 260:926-932, each of which are incorporated herein by reference in their entirety). Exemplary methods of transduction include, e.g., infection 5 employing viral vectors (see, e.g., U.S. Patent 4,405,712 and 4,650,764), calcium phosphate transfection (U.S. Patents 4,399,216 and 4,634,665), dextran sulfate transfection, electroporation, lipofection (see, e.g., U.S. Patents 4,394,448 and 4,619,794), cytofection, particle 10 bead bombardment, and the like. The heterologous nucleic acid can optionally include sequences which allow for its extrachromosomal (i.e., episomal) maintenance, or the heterologous nucleic acid can be donor nucleic acid that integrates into the genome of the host.

15 In a specific embodiment, said gene transfer vector is a viral vector, preferably a retroviral vector. Retroviral vectors are gene transfer plasmids that have an expression construct encoding an heterologous gene residing between two retroviral LTRs. Retroviral vectors typically 20 contain appropriate packaging signals that enable the retroviral vector, or RNA transcribed using the retroviral vector as a template, to be packaged into a viral virion in an appropriate packaging cell line (see, e.g., U.S. Patent 4,650,764).

25 Suitable retroviral vectors for use herein are described, for example, in U.S. Patents 5,399,346 and 5,252,479; and in WIPO publications WO 92/07573, WO 90/06997, WO 89/05345, WO 92/05266 and WO 92/14829, incorporated herein by reference, which provide a 30 description of methods for efficiently introducing nucleic acids into human cells using such retroviral vectors. Other retroviral vectors include, for example, mouse mammary tumor virus vectors (e.g., Shackleford et al., 1988, PNAS, USA, 85:9655-9659), and the like.

Various procedures are also well-known in the art for providing helper cells which produce retroviral vector particles which are essentially free of replicating virus. See, for example, U.S. Patent 4,650,764; Miller, Human Gene Therapy, 1:5-14 (1990); Markowitz, et al., Journal of Virology, 61(4):1120-1124 (1988); Watanabe, et al., Molecular and Cellular Biology, 3(12):2241-2249 (1983); Danos, et al., Proc. Natl. Acad. Sci., 85:6460-6464 (1988); and Bosselman, et al., Molecular and Cellular Biology, 7(5):1797-1806 (1987), which disclose procedures for producing viral vectors and helper cells which minimize the chances for producing a viral vector which includes a replicating virus.

Recombinant retroviruses suitable for carrying out the invention methods are produced employing well-known methods for producing retroviral virions. See, for example, U.S. Patent 4,650,764; Miller, Human Gene Therapy, 1:5-14 (1990); Markowitz, et al., Journal of Virology, 61(4):1120-1124 (1988); Watanabe, et al., Molecular and Cellular Biology, 3(12):2241-2249 (1983); Danos, et al., Proc. Natl. Acad. Sci., 85:6460-6464 (1988); and Bosselman, et al., Molecular and Cellular Biology, 7(5):1797-1806 (1987).

In accordance with another embodiment of the present invention, there are provided recombinant cells containing a nucleic acid encoding an invention modified ecdysone receptor. Exemplary eukaryotic cells for introducing invention expression vectors include, e.g., CV-1 cells, P19 cells and NT2/D1 cells (which are derived from human embryo carcinomas), COS cells, mouse L cells, Chinese hamster ovary (CHO) cells, primary human fibroblast cells, human embryonic kidney cells, African green monkey cells, HEK 293 (ATCC accession #CRL 1573; U.S. Patent No. 5,024,939), Ltk<sup>-</sup> cells (ATCC accession #CCL1.3), COS-7 cells (ATCC under accession #CRL 1651), DG44 cells (dhfr<sup>-</sup> CHO

cells; see, e.g., Urlaub et al. (1986) Cell. Molec. Genet. 12: 555), cultured primary tissues, cultured tumor cells, and the like. Presently preferred cells include CV-1 and 293 cells.

5 In accordance with another embodiment of the present invention, there is provided a transgenic mammal containing a nucleic acid encoding an invention modified ecdysone receptor. As used herein, the phrase "transgenic mammal" refers to a mammal that contains one or more  
10 inheritable expression constructs containing a recombinant modified ecdysone receptor transgene and/or an exogenous gene under the transcription control of an invention modified ecdysone response element. Preferably, an invention transgenic mammal also contains one or more  
15 inheritable expression constructs containing a member of the steroid/thyroid superfamily of receptors that functions as a silent partner for modified ecdysone receptor (e.g., RXR).

Methods of making transgenic mammals using a  
20 particular nucleic acid construct are well-known in the art. When preparing invention transgenic animals, it is preferred that two transgenic lines are generated. The first line will express, for example, RXR and a modified EcR (e.g., VpEcR). Tissue specificity is conferred by the  
25 selection of tissue-specific promoters (e.g., T-cell specific) that will then direct the expression of the receptors. A second line contains an ecdysone responsive promoter controlling the expression of an exogenous cDNA.

In a preferred embodiment of the present  
30 invention, an invention transgenic mammal contains one or more expression constructs containing nucleic acid encoding a modified ecdysone receptor, exogenous RXR, and an exogenous gene under the transcription control of an invention modified ecdysone response element. It has been

found that in transgenic mice containing an ecdysone inducible promoter (i.e., an invention modified ecdysone response element) and expressing a modified ecdysone receptor and RXR, muristerone treatment can activate gene expression. Thus, with tissue specific expression of the modified ecdysone receptor and RXR and timely hormone treatment, inducible gene expression can be achieved with spatial, dosage, and temporal specificity.

In accordance with another embodiment of the present invention, there are provided methods for inducing expression of an exogenous gene in a transgenic mammal containing a modified ecdysone receptor according to the invention, said method comprising:

introducing into said mammal a DNA construct encoding an exogenous gene under the transcription control of an ecdysone response element responsive to said modified ecdysone receptor; and

administering to said mammal an amount of ligand for said modified ecdysone receptor effective to induce expression of said exogenous gene.

As discussed hereinbefore, the modified ecdysone receptor forms a homodimer, or optionally a heterodimer in the presence of a silent partner of the steroid/thyroid hormone superfamily of receptors, and functions to activate transcription from an expression vector having a response element responsive to the particular homodimer or heterodimer formed.

In accordance with another embodiment of the present invention, there are provided methods for the induction of two different genes in a mammalian subject comprising: activating a first exogenous gene employing the invention ecdysone inducible system; and activating a

second gene using a tetracycline inducible system. The invention method for inducing two different genes is particularly advantagous because it permits the temporal, spatial, and dosage specific control of two exogenous  
5 genes.

The tetracycline inducible system is well-known in the art (see, e.g., Gossen et al. (1992) Proc. Natl. Acad. Sci. **89**, 5547-5551; Gossen et al. (1993) TIBS **18**, 471-475; Furth et al. (1994) Proc. Natl. Acad. Sci. **91**, 10 9302-9306; and Shockett et al. (1995) Proc. Natl. Acad. Sci. **92**, 6522-6526).

All U.S. and Foreign Patent publications, textbooks, and journal publications referred to herein are hereby expressly incorporated by reference in their  
15 entirety. The invention will now be described in greater detail by reference to the following non-limiting examples.

Example 1

Preparation of modified ecdysone receptors

Plasmid preparation:

20 The plasmids CMX-EcR, CMX-USP, CMX-FXR, CMX-hRXRa, EcREx5-AMTV-Luc, CMX-GEcR, MMTV-luc, and CMX-GR have been previously described (Yao, et al., Nature **366**:476-479 (1993) and Forman, et al. Cell **81**:687-693 (1995)).

25 The plasmid CMX-VpEcR was constructed by ligation of an EcoRI fragment of psk-EcR and CMX-Vp16.

The plasmid CMX-VgEcR was generated by site-directed mutagenesis of CMX-VpEcR using the Transformer Mutagenesis Kit (Clontech) and the mutagenic  
30 Oligonucleotide (SEQ ID NO:14):

5'-TACAAACGCCCTCACCTGTGGATCCTGCAAGGTGTTCTTCGACGCAGC-3'.

Mutagenesis of VpEcR to VgEcR altered the P-box region of the DNA binding domain of ecdysone receptor to resemble that of GR (Umesono and Evans, Cell 57:1139-1146 (1989)).

5 The following amino acids in the DNA-binding domain of the ecdysone receptor were altered: E282G, G283S, and G286V (E=glutamate, G=glycine, S=serine, V=valine).

The reporter construct EcREx4-ΔHSP-β-gal was constructed by oligomerizing two annealed oligonucleotides 10 containing the HSP-EcRE (Yao, et al., Nature 366:476-479 (1993)).

EcREx4-Sp1x3-ΔHSP-βgal was constructed by ligating the following annealed oligonucleotides into the Asp718 site of EcREx4-HSP-β-gal (SEQ ID NO:15):

15 5'-GTACTCCGGGGCGGGGCTATGCGGGGCGGGGCTAACGCTAGGGCGGGCA-3'

and (SEQ ID NO:16):

5'-GTACTCCCCGCCCCTAGCGATTAGCCCCGCCCCGCATAGCCCCGCC  
CGGGA-3'.

ΔHSP is a minimal promoter derived from the Drosophila heat 20 shock promoter with its enhancers deleted.

To generate the construct E/GREx4-ΔMTV-Luc, the following oligonucleotides (SEQ ID NO:17):

5'-AGCTCGATGGACAAGTGCATTGTTCTTGCTGAA-3' ;

and (SEQ ID NO:18):

25 5'-AGCTTTCAGCAAGAGAACATGCACTTGTCCATCG-3',

were annealed, multimerized, and ligated into the HindIII site of AMTV-Luc. The resulting reporter contained 4 copies of the invention modified ecdysone response element E/GRE.

5 To produce the plasmid pRC-ESH $\beta$ , a BglII/(XhoI) fragment containing EcREx4-Sp1x3-ΔHSP- $\beta$ -gal was subcloned into BglII/(NotI) digested pRC-CMV (Invitrogen, San Diego, CA), which contains a neomycin resistance gene.

Cell Culture and Transient Transfections:

10 CV-1 cells were maintained in DMEM supplemented with 10% Fetal Bovine Serum. Transient transfections were performed using DOTAP transfection reagent (Boehringer-Mannheim). Transfections using  $\beta$ -galactosidase as the reporter were assayed either by Galactolight  
15 luminescent assay (Tropix, Bedford, MA) or by standard liquid ONPG assay (Sigma, St. Louis, MO). The values were normalized by co-transfection of CMX-luciferase. Transfections using luciferase as the reporter were assayed by standard techniques using luciferin and ATP. These  
20 values were normalized by co-transfection of CMX- $\beta$ -galactosidase. Hormone treated cells were treated with ethanol, 50  $\mu$ M Juvenile Hormone III (Sigma), 1 $\mu$ M muristerone A (Zambon, Bresso, IT), or 1 $\mu$ M dexamethasone (Sigma) unless otherwise noted.

25 To maximize the sensitivity of the invention ecdysone inducible system, modifications of the ecdysone receptor were made. The N-terminal transactivation domain of the ecdysone receptor was replaced by the corresponding domain of the glucocorticoid receptor (GR), resulting in  
30 the modified ecdysone receptor GEcR (See Figure 1D). CV-1 cells were transfected with the plasmid CMX-GEcR encoding the modified ecdysone receptor as discussed above. After transfection, cells were either treated with ethanol or 1 $\mu$ M muristerone A. This hybrid modified ecdysone receptor

boosted muristerone responsiveness from 3- to 11-fold in a transient transfection assay (Fig. 1A). Replacement of the natural heterodimeric partner for the ecdysone receptor, USP, by its mammalian homologue, the retinoid X receptor RXR, produced a more potent ligand dependent heterodimer, providing a 34 fold induction (Fig. 1A).

A more potent heterodimer, however, was obtained by combining RXR and VpEcR, an N-terminal truncation of the ecdysone receptor attached to the VP16 activation domain, resulting in a 212 fold induction (Fig. 1A and 1D). Different from most nuclear receptor/VP16 fusion proteins which exhibit high constitutive activity, VpEcR generates ligand dependent superinduction while maintaining a very low basal activity (Underhill et al., Mol. Encod. 8:274-285 (1994) and Perlmann et al., Genes & Devel. 7:1411-1422 (1993)).

In addition, the reporter vector was also modified by inserting consensus binding sites for the ubiquitous transcription factor Sp1 between the minimal promoter and the ecdysone response elements (Kamine et al., Proc. Natl. Acad. Sci. 88:8510-8514 (1991) and Strahle et al., EMBO 7:3389-3395 (1988)). The addition of Sp1 sites to the ecdysone responsive promoter increases the absolute activity 5-fold (Fig. 1A).

25

#### Example 2

##### Construction of a novel ecdysone response element

Although no mammalian transcription factors have been shown to have a natural enhancer element like the ecdysone response element, which is composed of two inverted half-sites of the sequence AGGTCA spaced by one nucleotide, it is difficult to preclude such a possibility. The recently cloned farnesoid X receptor (FXR), can very weakly activate certain synthetic promoters containing an

ecdysone response element in response to extremely high concentrations of farnesoids (Forman et al., Cell 81:687-693 (1995)).

In FXR containing cells and in transgenic mice,  
5 activation of gene expression by endogenous receptors would  
create undesirable background levels of reporter protein.  
To circumvent this potential problem, the DNA binding  
specificity of VpEcR was altered to mimic that of GR, which  
binds as a homodimer to an inverted repeat of the sequence  
10 AGAACCA, spaced by three nucleotides. This altered binding  
specificity was achieved by mutating three amino acid  
residues of VpEcR in the P-box of the DNA binding domain,  
a region previously shown to be essential for DNA sequence  
recognition (Umesono and Evans, Cell 57:1139-1146 (1989)).  
15 This new hybrid modified ecdysone receptor is referred  
herein as VgEcR and is responsive to a new hybrid response  
element referred to herein as the E/GRE (SEQ ID NO:12),  
which contains two different half-site motifs, RGBNNM and  
RGNNCA, spaced by one nucleotide (Fig. 1B). This new  
20 response element is a hybrid between the glucocorticoid  
response element (GRE) and that of type II nuclear  
receptors like RXR, EcR, retinoic acid receptor (RAR),  
thyroid hormone receptor (T3R), etc. Although FXR can  
activate a promoter containing the wild type ecdysone  
25 response element, it cannot activate one containing the  
E/GRE (Fig 1B; note log scale). The E/GRE reporter is not  
activated by GR nor does VgEcR activate a dexamethasone  
responsive promoter (Fig 1C).

#### Example 3

##### 30 Assay for Ecdysone responsiveness in stable cell lines

Stable cell lines were generated containing the  
modified ecdysone receptor VpEcR, a heterodimeric partner  
(RXR), and an ecdysone inducible reporter (Figure 2). 293  
cells were transfected with the following linearized

plasmids, pRC-ESHB, EcRE<sub>x</sub>5-ΔMTV-Luc, CMX-VpEcR, and CMX-hRXRa. The following day, the cells were split 1:10 and were allowed to recover one day prior to selection with 1mg/ml G418 (GIBCO). After 14 days of selection, 14 individual clones were isolated and grown separately in the presence of 0.5mg/ml G418. Of 14 G418 resistant clones, 10 demonstrated differing degrees of muristerone responsiveness.

One of these cell lines, N13, was grown in the presence or absence of 1μM muristerone for 20 hours. Cell lysates were then assayed for β-galactosidase and luciferase activities as described in Example 1. X-gal staining was performed on the stable cell lines. Cells were fixed briefly with 10% formaldehyde in PBS and then stained with X-Gal (Molecular Probes, Eugene, OR) for 2 to 6 hours. After 24 hours of treatment with 1μM muristerone, 100% of the cells turned dark blue after 3 hours of staining. Thus, mammalian cells containing the modified ecdysone receptor VpEcR, a heterodimeric partner (RXR), and a reporter gene construct regulated by a modified ecdysone response element, function to efficiently express an exogenous gene in response to a ligand, e.g., ecdysone.

A dose-response assay was conducted by growing N13 cells with varying concentrations of muristerone for 36 hours and then assaying for β-galactosidase activity (using the well-known ONPG assay), or the cells were assayed for luciferase activity. Dose response curves of stably integrated β-galactosidase and luciferase reporters in N13 cells revealed that inducibility approaching 3 orders of magnitude can be achieved at a final concentration 10μM muristerone (Figure 3A). One-hundred fold induction was achieved by muristerone concentrations as low as 100nM (Figure 3A).

Finally, the kinetics of muristerone mediated induction was measured. N13 cells were grown in separate wells in the presence of 1 $\mu$ M muristerone, harvested at varying times, and assayed for luciferase activity.

5 Inductions of 100-fold in 3 hrs., 1000 fold in 8 hrs., and maximal effects of 20,000 fold after 20 hours of treatment were observed (Figure 3B). Similar results were observed in stable lines containing CMX-VgEcR and the E/GRE reporters.

10

Example 4Bioavailability and activity of muristerone

In order to use muristerone as a potential hormone in mice, its toxicity and bioavailability was examined. For toxicity studies, adult mice were injected 15 intraperitoneally with 20mg of muristerone A suspended in sesame oil. The mice were then observed for approximately two months. For teratogenic studies, pregnant mice were injected with 20mg of muristerone A suspended in sesame oil and both the mother and pups were observed for three 20 months. The results indicate that muristerone maintains its activity when injected into mice, and that it is neither toxic, teratogenic, nor inactivated by serum binding proteins. In addition to the inert qualities of muristerone (an ecdysone), overexpression of VpEcR and RXR 25 appears not to be toxic.

For muristerone bioavailability studies, adult mice were injected intraperitoneally with sesame oil with or without 10mg of muristerone, and were subsequently sacrificed for serum collection. After twelve hours, blood 30 was drawn from the mice, and the serum was isolated by brief centrifugation of the whole blood. In order to conduct transfection assays to test for muristerone activity, serum from sesame oil injected mice was divided, and half was supplemented with muristerone to a final

concentration of 10 $\mu$ M. The three batches of mouse serum were diluted 1:10 in DMEM and placed onto CV-1 cells transfected with CMX-GEcR, CMX-hRXRa, and EcREx5-DMTV-Luc.

The results are shown in Figure 4 and indicate  
5 that serum from muristerone treated mice yielded a luciferase activity comparable to that seen from untreated mouse serum supplemented with 1 $\mu$ M muristerone. The results indicate that single-site injected material should be widely circulated, and that there is little or no blunting  
10 of activity due to association with serum proteins.

Example 5

Muristerone dependent gene expression in transgenic mice

To produce transgenic mice, the following DNA constructs were prepared and subsequently injected into  
15 fertilized eggs: CD3-VpEcR, CD3-RXR, ESH $\beta$  (Lee et al., J. Exp. Med. 175:1013-1025 (1992)). Two separate lines of transgenic mice were generated harboring either an ecdysone inducible reporter, ESH $\beta$ , or a T-cell specific expression construct of VpEcR and RXR, respectively. The former are  
20 referred to as reporter mice, the latter are referred to as receptor mice, and double transgenic mice are referred to as receptor/reporter mice. Constructs CD3-VpEcR and CD3-RXR were mixed and coinjected, while ESH $\beta$  was injected alone. Primary genotyping was performed by Southern blot  
25 analysis and the transmission of transgenic mice was monitored by dot blot analysis. Receptor mice were analyzed for VpEcR and RXR expression by Northern blot analysis of RNA collected from these mice. For Northern blot analysis, 15 $\mu$ g of total RNA obtained from the thymus,  
30 and various tissues as a control, was run on a denaturing gel and blotted onto a nitrocellulose membrane. The blot was probed with a radiolabeled  $\beta$ -gal-specific probe and exposed on film for 2 days. These receptor mice were healthy, fertile, and appeared normal by visual inspection.

In addition, the transgene was transferred to the offspring as expected by Mendelian genetics. This data suggests that overexpression of VpEcR and RXR in T-cells is not toxic.

Receptor expressing mice were bred with reporter 5 mice (containing ESH $\beta$ ) to produce double transgenic receptor/reporter mice. Adult receptor/reporter transgenic mice (genotype=CD3-VpEcR; CD3-RXR; and ESH $\beta$ ) were injected intraperitonealy with sesame oil with or without 10mg of muristerone. Subsequently, a Northern blot analysis was 10 performed on the double transgenic lines using RNA isolated 48 hours after treatment from various tissues including the thymus, brain and liver, to test for the specific induction of an ecdysone inducible promoter. The probe used was specific to the activity of the ecdysone inducible 15 promoter. The autoradiograph was exposed for 36 hrs. The results of the Northern analysis indicate that muristerone treatment of the transgenic mouse containing a T-cell specific expression construct of VpEcR and RXR, and the ecdysone inducible reporter ESH $\beta$ , caused a significant 20 induction from an ecdysone inducible promoter in the thymus, while low basal activity is observed in its absence.

While the invention has been described in detail with reference to certain preferred embodiments thereof, it 25 will be understood that modifications and variations are within the spirit and scope of that which is described and claimed.

## SEQUENCE LISTING

## (1) GENERAL INFORMATION:

(i) APPLICANT: THE SALK INSTITUTE FOR BIOLOGICAL STUDIES et al.

(ii) TITLE OF INVENTION: HORMONE-MEDIATED METHODS FOR MODULATING EXPRESSION OF EXOGENOUS GENES IN MAMMALIAN SYSTEMS, AND PRODUCTS RELATED THERETO

(iii) NUMBER OF SEQUENCES: 18

(iv) CORRESPONDENCE ADDRESS:

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(F) ZIP: 92121

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk  
(B) COMPUTER: IBM PC compatible  
(C) OPERATING SYSTEM: PC-DOS/MS-DOS  
(D) SOFTWARE: PatentIn Release #1.0, Version #1.25

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER: PCT/US 97/05330  
(B) FILING DATE: 27/03/1997  
(C) CLASSIFICATION:

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: Reiter, Stephen E.  
(B) REGISTRATION NUMBER: 31,192  
(C) REFERENCE/DOCKET NUMBER: SALK1520WO

(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: 619-677-1409  
(B) TELEFAX: 619-677-1465

## (2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 71 amino acids  
(B) TYPE: amino acid  
(C) STRANDEDNESS: single  
(D) TOPOLOGY: both

(ii) MOLECULE TYPE: protein

(v) FRAGMENT TYPE: internal

RECTIFIED SHEET (RULE 91)  
ISA/EP

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

Xaa	Cys Xaa Xaa Cys Xaa Xaa Asp Xaa Ala Xaa Gly Xaa Tyr Xaa Xaa		
	1	5	10
			15
Xaa	Xaa Cys Xaa Xaa Cys Lys Xaa Phe Phe Xaa Arg Xaa Xaa Xaa Xaa		
	20	25	30
Cys	Xaa Xaa Xaa Xaa Xaa Xaa Cys Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa		
	35	40	45
Xaa	Xaa Xaa Xaa Lys Xaa Xaa Arg Xaa Xaa Cys Xaa Xaa Cys Arg Xaa		
	50	55	60
	Lys Cys Xaa Xaa Xaa Gly Met		
	65	70	

## (2) INFORMATION FOR SEQ ID NO:2:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 5 amino acids
  - (B) TYPE: amino acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: unknown
- (ii) MOLECULE TYPE: peptide
- (v) FRAGMENT TYPE: internal

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

Glu	Gly	Cys	Lys	Gly
1			5	

## (2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 5 amino acids
  - (B) TYPE: amino acid
  - (C) STRANDEDNESS: single
  - (D) TOPOLOGY: unknown
- (ii) MOLECULE TYPE: peptide

## (v) FRAGMENT TYPE: internal

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

Gly Ser Cys Lys Val  
1 5

## (2) INFORMATION FOR SEQ ID NO:4:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 2241 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: both
- (D) TOPOLOGY: both

## (ii) MOLECULE TYPE: cDNA

## (ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1..2241
- (D) OTHER INFORMATION: /product= "VgEcR"

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

ATG GCC CCC CCG ACC GAT GTC AGC CTG GGG GAC GAG CTC CAC TTA GAC  
48  
Met Ala Pro Pro Thr Asp Val Ser Leu Gly Asp Glu Leu His Leu Asp

1 5 10 15

GGC GAG GAC GTG GCG ATG GCG CAT GCC GAC GCG CTA GAC GAT TTC GAT  
96  
Gly Glu Asp Val Ala Met Ala His Ala Asp Ala Leu Asp Asp Phe Asp

20 25 30

CTG GAC ATG TTG GGG GAC GGG GAT TCC CCG GGT CCG GGA TTT ACC CCC  
144  
Leu Asp Met Leu Gly Asp Gly Asp Ser Pro Gly Pro Phe Thr Pro

35 40 45

CAC GAC TCC GCC CCC TAC GGC GCT CTG GAT ATG GCC GAC TTC GAG TTT  
192  
His Asp Ser Ala Pro Tyr Gly Ala Leu Asp Met Ala Asp Phe Glu Phe

50 55 60

GAG CAG ATG TTT ACC GAT GCC CTT GGA ATT GAC GAG TAC GGT GGG AAG  
240  
Glu Gln Met Phe Thr Asp Ala Leu Gly Ile Asp Glu Tyr Gly Lys

65                   70                   75                   80

CTT CTA GGT ACC TCT AGA AGG ATA TCG AAT TCT ATA TCT TCA GGT CGC  
288  
Leu Leu Gly Thr Ser Arg Arg Ile Ser Asn Ser Ile Ser Ser Gly Arg

85                   90                   95

GAT GAT CTC TCG CCT TCG AGC AGC TTG AAC GGA TAC TCG GCG AAC GAA  
336  
Asp Asp Leu Ser Pro Ser Ser Leu Asn Gly Tyr Ser Ala Asn Glu

100                105                110

AGC TGC GAT GCG AAG AAG AGC AAG AAG GGA CCT GCG CCA CGG GTG CAA  
384  
Ser Cys Asp Ala Lys Lys Ser Lys Lys Gly Pro Ala Pro Arg Val Gln

115                120                125

GAG GAG CTG TGC CTG GTT TGC GGC GAC AGG GCC TCC GGC TAC CAC TAC  
432  
Glu Glu Leu Cys Leu Val Cys Gly Asp Arg Ala Ser Gly Tyr His Tyr

130                135                140

AAC GCC CTC ACC TGT GGA TCC TGC AAG GTG TTC TTT CGA CGC AGC GTT  
480  
Asn Ala Leu Thr Cys Gly Ser Cys Lys Val Phe Phe Arg Arg Ser Val

145                150                155                160

ACG AAG AGC GCC GTC TAC TGC AAG TTC GGG CGC GCC TGC GAA ATG  
528  
Thr Lys Ser Ala Val Tyr Cys Cys Lys Phe Gly Arg Ala Cys Glu Met

165                170                175

GAC ATG TAC ATG AGG CGA AAG TGT CAG GAG TGC CGC CTG AAA AAG TGC  
576  
Asp Met Tyr Met Arg Arg Lys Cys Gln Glu Cys Arg Leu Lys Lys Cys

180                185                190

CTG GCC GTG GGT ATG CGG CCG GAA TGC GTC GTC CCG GAG AAC CAA TGT  
624  
Leu Ala Val Gly Met Arg Pro Glu Cys Val Val Pro Glu Asn Gln Cys  
195 200 205

GCG ATG AAG CGG CGC GAA AAG AAG GCC CAG AAG GAG AAG GAC AAA ATG  
672  
Ala Met Lys Arg Arg Glu Lys Lys Ala Gln Lys Glu Lys Asp Lys Met  
210 215 220

ACC ACT TCG CCG AGC TCT CAG CAT GGC GGC AAT GGC AGC TTG GCC TCT  
720  
Thr Thr Ser Pro Ser Ser Gln His Gly Gly Asn Gly Ser Leu Ala Ser  
225 230 235 240

GGT GGC GGC CAA GAC TTT GTT AAG AAG GAG ATT CTT GAC CTT ATG ACA  
768  
Gly Gly Gly Gln Asp Phe Val Lys Lys Glu Ile Leu Asp Leu Met Thr  
245 250 255

TGC GAG CCG CCC CAG CAT GCC ACT ATT CCG CTA CTA CCT GAT GAA ATA  
816  
Cys Glu Pro Pro Gln His Ala Thr Ile Pro Leu Leu Pro Asp Glu Ile  
260 265 270

TTG GCC AAG TGT CAA GCG CGC AAT ATA CCT TCC TTA ACG TAC AAT CAG  
864  
Leu Ala Lys Cys Gln Ala Arg Asn Ile Pro Ser Leu Thr Tyr Asn Gln  
275 280 285

TTG GCC GTT ATA TAC AAG TTA ATT TGG TAC CAG GAT GGC TAT GAG CAG  
912  
Leu Ala Val Ile Tyr Lys Leu Ile Trp Tyr Gln Asp Gly Tyr Glu Gln  
290 295 300

CCA TCT GAA GAG GAT CTC AGG CGT ATA ATG AGT CAA CCC GAT GAG AAC  
960  
Pro Ser Glu Glu Asp Leu Arg Arg Ile Met Ser Gln Pro Asp Glu Asn  
305 310 315 320

50

GAG AGC CAA ACG GAC GTC AGC TTT CGG CAT ATA ACC GAG ATA ACC ATA  
1008  
Glu Ser Gln Thr Asp Val Ser Phe Arg His Ile Thr Glu Ile Thr Ile

325                   330                   335

CTC ACG GTC CAG TTG ATT GTT GAG TTT GCT AAA GGT CTA CCA GCG TTT  
1056  
Leu Thr Val Gln Leu Ile Val Glu Phe Ala Lys Gly Leu Pro Ala Phe

340                   345                   350

ACA AAG ATA CCC CAG GAG GAC CAG ATC ACG TTA CTA AAG GCC TGC TCG  
1104  
Thr Lys Ile Pro Gln Glu Asp Gln Ile Thr Leu Leu Lys Ala Cys Ser

355                   360                   365

TCG GAG GTG ATG ATG CTG CGT ATG GCA CGA CGC TAT GAC CAC AGC TCG  
1152  
Ser Glu Val Met Met Leu Arg Met Ala Arg Arg Tyr Asp His Ser Ser

370                   375                   380

GAC TCA ATA TTC TTC GCG AAT AAT AGA TCA TAT ACG CGG GAT TCT TAC  
1200  
Asp Ser Ile Phe Phe Ala Asn Asn Arg Ser Tyr Thr Arg Asp Ser Tyr  
385                   390                   395                   400

AAA ATG GCC GGA ATG GCT GAT AAC ATT GAA GAC CTG CTG CAT TTC TGC  
1248  
Lys Met Ala Gly Met Ala Asp Asn Ile Glu Asp Leu Leu His Phe Cys

405                   410                   415

CGC CAA ATG TTC TCG ATG AAG GTG GAC AAC GTC GAA TAC GCG CTT CTC  
1296  
Arg Gln Met Phe Ser Met Lys Val Asp Asn Val Glu Tyr Ala Leu Leu  
420                   425                   430

ACT GCC ATT GTG ATC TTC TCG GAC CGG CCG GGC CTG GAG AAG GCC CAA  
1344  
Thr Ala Ile Val Ile Phe Ser Asp Arg Pro Gly Leu Glu Lys Ala Gln

435                   440                   445

51

CTA GTC GAA GCG ATC CAG AGC TAC TAC ATC GAC ACG CTA CGC ATT TAT  
1392  
Leu Val Glu Ala Ile Gln Ser Tyr Tyr Ile Asp Thr Leu Arg Ile Tyr

450 455 460

ATA CTC AAC CGC CAC TGC GGC GAC TCA ATG AGC CTC GTC TTC TAC GCA  
1440  
Ile Leu Asn Arg His Cys Gly Asp Ser Met Ser Leu Val Phe Tyr Ala

465 470 475 480

AAG CTG CTC TCG ATC CTC ACC GAG CTG CGT ACG CTG GGC AAC CAG AAC  
1488  
Lys Leu Leu Ser Ile Leu Thr Glu Leu Arg Thr Leu Gly Asn Gln Asn

485 490 495

GCC GAG ATG TGT TTC TCA CTA AAG CTC AAA AAC CGC AAA CTG CCC AAG  
1536  
Ala Glu Met Cys Phe Ser Leu Lys Leu Lys Asn Arg Lys Leu Pro Lys

500 505 510

TTC CTC GAG GAG ATC TGG GAC GTT CAT GCC ATC CCG CCA TCG GTC CAG  
1584  
Phe Leu Glu Glu Ile Trp Asp Val His Ala Ile Pro Pro Ser Val Gln

515 520 525

TCG CAC CTT CAG ATT ACC CAG GAG AAC GAG CGT CTC GAG CGG GCT  
1632  
Ser His Leu Gln Ile Thr Gln Glu Glu Asn Glu Arg Leu Glu Arg Ala

530 535 540

GAG CGT ATG CGG GCA TCG GTT GGG GGC GCC ATT ACC GCC GGC ATT GAT  
1680  
Glu Arg Met Arg Ala Ser Val Gly Gly Ala Ile Thr Ala Gly Ile Asp

545 550 555 560

TGC GAC TCT GCC ACT TCG GCG GCG GCA GCC GCG GCC CAG CAT CAG  
1728  
Cys Asp Ser Ala Ser Thr Ser Ala Ala Ala Ala Ala Gln His Gln

565 570 575

52

CCT CAG CCT CAG CCC CAG CCC CAA CCC TCC TCC CTG ACC CAG AAC GAT  
1776  
Pro Gln Pro Gln Pro Gln Pro Ser Ser Leu Thr Gln Asn Asp

580 585 590

TCC CAG CAC CAG ACA CAG CCG CAG CTA CAA CCT CAG CTA CCA CCT CAG  
1824  
Ser Gln His Gln Thr Gln Pro Gln Leu Gln Pro Gln Leu Pro Pro Gln

595 600 605

CTG CAA GGT CAA CTG CAA CCC CAG CTC CAA CCA CAG CTT CAG ACG CAA  
1872  
Leu Gln Gly Gln Leu Gln Pro Gln Leu Gln Pro Gln Leu Gln Thr Gln

610 615 620

CTC CAG CCA CAG ATT CAA CCA CAG CCA CAG CTC CTT CCC GTC TCC GCT  
1920  
Leu Gln Pro Gln Ile Gln Pro Gln Pro Gln Leu Leu Pro Val Ser Ala

625 630 635 640

CCC GTG CCC GCC TCC GTA ACC GCA CCT GGT TCC TTG TCC GCG GTC AGT  
1968  
Pro Val Pro Ala Ser Val Thr Ala Pro Gly Ser Leu Ser Ala Val Ser

645 650 655

ACG AGC AGC GAA TAC ATG GGC GGA AGT GCG GCC ATA GGA CCC ATC ACG  
2016  
Thr Ser Ser Glu Tyr Met Gly Gly Ser Ala Ala Ile Gly Pro Ile Thr

660 665 670

CCG GCA ACC ACC AGC AGT ATC ACG GCT GCC GTT ACC GCT AGC TCC ACC  
2064  
Pro Ala Thr Thr Ser Ser Ile Thr Ala Ala Val Thr Ala Ser Ser Thr

675 680 685

ACA TCA GCG GTA CCG ATG GGC AAC GGA GTT GGA GTC GGT GTT GGG GTG  
2112  
Thr Ser Ala Val Pro Met Gly Asn Gly Val Gly Val Gly Val Gly Val

690 695 700

53

GGC GGC AAC GTC AGC ATG TAT GCG AAC GCC CAG ACG GCG ATG GCC TTG  
2160

Gly Gly Asn Val Ser Met Tyr Ala Asn Ala Gln Thr Ala Met Ala Leu

705                   710                   715                   720

ATG GGT GTA GCC CTG CAT TCG CAC CAA GAG CAG CTT ATC GGG GGA GTG  
2208

Met Gly Val Ala Leu His Ser His Gln Glu Gln Leu Ile Gly Gly Val

725                   730                   735

GCG GTT AAG TCG GAG CAC TCG ACG ACT GCA TAG  
2241

Ala Val Lys Ser Glu His Ser Thr Thr Ala  
740                   745

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 746 amino acids  
(B) TYPE: amino acid  
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

Met Ala Pro Pro Thr Asp Val Ser Leu Gly Asp Glu Leu His Leu Asp  
1                   5                   10                   15

Gly Glu Asp Val Ala Met Ala His Ala Asp Ala Leu Asp Asp Phe Asp  
20                   25                   30

Leu Asp Met Leu Gly Asp Gly Asp Ser Pro Gly Pro Gly Phe Thr Pro  
35                   40                   45

His Asp Ser Ala Pro Tyr Gly Ala Leu Asp Met Ala Asp Phe Glu Phe  
50                   55                   60

Glu Gln Met Phe Thr Asp Ala Leu Gly Ile Asp Glu Tyr Gly Lys  
65                   70                   75                   80

Leu Leu Gly Thr Ser Arg Arg Ile Ser Asn Ser Ile Ser Ser Gly Arg  
85                   90                   95

Asp Asp Leu Ser Pro Ser Ser Leu Asn Gly Tyr Ser Ala Asn Glu

54

100

105

110

Ser Cys Asp Ala Lys Lys Ser Lys Lys Gly Pro Ala Pro Arg Val Gln  
115 120 125

Glu Glu Leu Cys Leu Val Cys Gly Asp Arg Ala Ser Gly Tyr His Tyr  
130 135 140

Asn Ala Leu Thr Cys Gly Ser Cys Lys Val Phe Phe Arg Arg Ser Val  
145 150 155 160

Thr Lys Ser Ala Val Tyr Cys Cys Lys Phe Gly Arg Ala Cys Glu Met  
165 170 175

Asp Met Tyr Met Arg Arg Lys Cys Gln Glu Cys Arg Leu Lys Lys Cys  
180 185 190

Leu Ala Val Gly Met Arg Pro Glu Cys Val Val Pro Glu Asn Gln Cys  
195 200 205

Ala Met Lys Arg Arg Glu Lys Lys Ala Gln Lys Glu Lys Asp Lys Met  
210 215 220

Thr Thr Ser Pro Ser Ser Gln His Gly Gly Asn Gly Ser Leu Ala Ser  
225 230 235 240

Gly Gly Gly Gln Asp Phe Val Lys Glu Ile Leu Asp Leu Met Thr  
245 250 255

Cys Glu Pro Pro Gln His Ala Thr Ile Pro Leu Leu Pro Asp Glu Ile  
260 265 270

Leu Ala Lys Cys Gln Ala Arg Asn Ile Pro Ser Leu Thr Tyr Asn Gln  
275 280 285

Leu Ala Val Ile Tyr Lys Leu Ile Trp Tyr Gln Asp Gly Tyr Glu Gln  
290 295 300

Pro Ser Glu Glu Asp Leu Arg Arg Ile Met Ser Gln Pro Asp Glu Asn  
305 310 315 320

Glu Ser Gln Thr Asp Val Ser Phe Arg His Ile Thr Glu Ile Thr Ile  
325 330 335

Leu Thr Val Gln Leu Ile Val Glu Phe Ala Lys Gly Leu Pro Ala Phe  
340 345 350

Thr Lys Ile Pro Gln Glu Asp Gln Ile Thr Leu Leu Lys Ala Cys Ser  
355 360 365

Ser Glu Val Met Met Leu Arg Met Ala Arg Arg Tyr Asp His Ser Ser  
370 375 380

Asp Ser Ile Phe Phe Ala Asn Asn Arg Ser Tyr Thr Arg Asp Ser Tyr  
385 390 395 400

Lys Met Ala Gly Met Ala Asp Asn Ile Glu Asp Leu Leu His Phe Cys  
405 410 415

Arg Gln Met Phe Ser Met Lys Val Asp Asn Val Glu Tyr Ala Leu Leu  
420 425 430

Thr Ala Ile Val Ile Phe Ser Asp Arg Pro Gly Leu Glu Lys Ala Gln  
435 440 445

Leu Val Glu Ala Ile Gln Ser Tyr Tyr Ile Asp Thr Leu Arg Ile Tyr  
450 455 460

Ile Leu Asn Arg His Cys Gly Asp Ser Met Ser Leu Val Phe Tyr Ala  
465 470 475 480

Lys Leu Leu Ser Ile Leu Thr Glu Leu Arg Thr Leu Gly Asn Gln Asn  
485 490 495

Ala Glu Met Cys Phe Ser Leu Lys Leu Lys Asn Arg Lys Leu Pro Lys  
500 505 510

Phe Leu Glu Glu Ile Trp Asp Val His Ala Ile Pro Pro Ser Val Gln  
515 520 525

Ser His Leu Gln Ile Thr Gln Glu Glu Asn Glu Arg Leu Glu Arg Ala  
530 535 540

Glu Arg Met Arg Ala Ser Val Gly Gly Ala Ile Thr Ala Gly Ile Asp  
545 550 555 560

Cys Asp Ser Ala Ser Thr Ser Ala Ala Ala Ala Ala Gln His Gln

56

565

570

575

Pro Gln Pro Gln Pro Gln Pro Gln Pro Ser Ser Leu Thr Gln Asn Asp  
580 585 590

Ser Gln His Gln Thr Gln Pro Gln Leu Gln Pro Gln Leu Pro Pro Gln  
595 600 605

Leu Gln Gly Gln Leu Gln Pro Gln Leu Gln Pro Gln Leu Gln Thr Gln  
610 615 620

Leu Gln Pro Gln Ile Gln Pro Gln Pro Gln Leu Leu Pro Val Ser Ala  
625 630 635 640

Pro Val Pro Ala Ser Val Thr Ala Pro Gly Ser Leu Ser Ala Val Ser  
645 650 655

Thr Ser Ser Glu Tyr Met Gly Gly Ser Ala Ala Ile Gly Pro Ile Thr  
660 665 670

Pro Ala Thr Thr Ser Ser Ile Thr Ala Ala Val Thr Ala Ser Ser Thr  
675 680 685

Thr Ser Ala Val Pro Met Gly Asn Gly Val Gly Val Gly Val Gly Val  
690 695 700

Gly Gly Asn Val Ser Met Tyr Ala Asn Ala Gln Thr Ala Met Ala Leu  
705 710 715 720

Met Gly Val Ala Leu His Ser His Gln Glu Gln Leu Ile Gly Gly Val  
725 730 735

Ala Val Lys Ser Glu His Ser Thr Thr Ala  
740 745

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 2241 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: both  
(D) TOPOLOGY: both

(ii) MOLECULE TYPE: cDNA

## (ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1..2241
- (D) OTHER INFORMATION: /product= "VpEcR"

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

ATG GCC CCC CCG ACC GAT GTC AGC CTG GGG GAC GAG CTC CAC TTA GAC  
 48  
 Met Ala Pro Pro Thr Asp Val Ser Leu Gly Asp Glu Leu His Leu Asp

1	5	10	15
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GGC GAG GAC GTG GCG ATG GCG CAT GCC GAC GCG CTA GAC GAT TTC GAT  
 96  
 Gly Glu Asp Val Ala Met Ala His Ala Asp Ala Leu Asp Asp Phe Asp

20	25	30
----	----	----

CTG GAC ATG TTG GGG GAC GGG GAT TCC CCG GGT CCG GGA TTT ACC CCC  
 144  
 Leu Asp Met Leu Gly Asp Gly Asp Ser Pro Gly Pro Phe Thr Pro

35	40	45
----	----	----

CAC GAC TCC GCC CCC TAC GGC GCT CTG GAT ATG GCC GAC TTC GAG TTT  
 192  
 His Asp Ser Ala Pro Tyr Gly Ala Leu Asp Met Ala Asp Phe Glu Phe

50	55	60
----	----	----

GAG CAG ATG TTT ACC GAT GCC CTT GGA ATT GAC GAG TAC GGT GGG AAG  
 240  
 Glu Gln Met Phe Thr Asp Ala Leu Gly Ile Asp Glu Tyr Gly Lys

65	70	75	80
----	----	----	----

CTT CTA GGT ACC TCT AGA AGG ATA TCG AAT TCT ATA TCT TCA GGT CGC  
 288  
 Leu Leu Gly Thr Ser Arg Arg Ile Ser Asn Ser Ile Ser Ser Gly Arg

85	90	95
----	----	----

GAT GAT CTC TCG CCT TCG AGC AGC TTG AAC GGA TAC TCG GCG AAC GAA  
 336  
 Asp Asp Leu Ser Pro Ser Ser Leu Asn Gly Tyr Ser Ala Asn Glu

100	105	110
-----	-----	-----

AGC TGC GAT GCG AAG AAG AGC AAG AAG GGA CCT GCG CCA CGG GTG CAA  
384

Ser Cys Asp Ala Lys Lys Ser Lys Lys Gly Pro Ala Pro Arg Val Gln

115

120

125

GAG GAG CTG TGC CTG GTT TGC GGC GAC AGG GCC TCC GGC TAC CAC TAC  
432

Glu Glu Leu Cys Leu Val Cys Gly Asp Arg Ala Ser Gly Tyr His Tyr

130

135

140

AAC GCC CTC ACC TGT GAG GGC TGC AAG GGG TTC TTT CGA CGC AGC GTT  
480

Asn Ala Leu Thr Cys Glu Gly Cys Lys Gly Phe Phe Arg Arg Ser Val

145

150

155

160

ACG AAG AGC GCC GTC TAC TGC TGC AAG TTC GGG CGC GCC TGC GAA ATG  
528

Thr Lys Ser Ala Val Tyr Cys Cys Lys Phe Gly Arg Ala Cys Glu Met

165

170

175

GAC ATG TAC ATG AGG CGA AAG TGT CAG GAG TGC CGC CTG AAA AAG TGC  
576

Asp Met Tyr Met Arg Arg Lys Cys Gln Glu Cys Arg Leu Lys Lys Cys

180

185

190

CTG GCC GTG GGT ATG CGG CCG GAA TGC GTC GTC CCG GAG AAC CAA TGT  
624

Leu Ala Val Gly Met Arg Pro Glu Cys Val Val Pro Glu Asn Gln Cys

195

200

205

GCG ATG AAG CGG CGC GAA AAG AAG GCC CAG AAG GAG AAG GAC AAA ATG  
672

Ala Met Lys Arg Arg Glu Lys Lys Ala Gln Lys Glu Lys Asp Lys Met

210

215

220

ACC ACT TCG CCG AGC TCT CAG CAT GGC GGC AAT GGC AGC TTG GCC TCT  
720

Thr Thr Ser Pro Ser Ser Gln His Gly Gly Asn Gly Ser Leu Ala Ser

225

230

235

240

GGT GGC GGC CAA GAC TTT GTT AAG AAG GAG ATT CTT GAC CTT ATG ACA  
768  
Gly Gly Gly Gln Asp Phe Val Lys Lys Glu Ile Leu Asp Leu Met Thr

245 250 255

TGC GAG CCG CCC CAG CAT GCC ACT ATT CCG CTA CTA CCT GAT GAA ATA  
816  
Cys Glu Pro Pro Gln His Ala Thr Ile Pro Leu Leu Pro Asp Glu Ile  
260 265 270

TTG GCC AAG TGT CAA GCG CGC AAT ATA CCT TCC TTA ACG TAC AAT CAG  
864  
Leu Ala Lys Cys Gln Ala Arg Asn Ile Pro Ser Leu Thr Tyr Asn Gln  
275 280 285

TTG GCC GTT ATA TAC AAG TTA ATT TGG TAC CAG GAT GGC TAT GAG CAG  
912  
Leu Ala Val Ile Tyr Lys Leu Ile Trp Tyr Gln Asp Gly Tyr Glu Gln  
290 295 300

CCA TCT GAA GAG GAT CTC AGG CGT ATA ATG AGT CAA CCC GAT GAG AAC  
960  
Pro Ser Glu Glu Asp Leu Arg Arg Ile Met Ser Gln Pro Asp Glu Asn  
305 310 315 320

GAG AGC CAA ACG GAC GTC AGC TTT CGG CAT ATA ACC GAG ATA ACC ATA  
1008  
Glu Ser Gln Thr Asp Val Ser Phe Arg His Ile Thr Glu Ile Thr Ile  
325 330 335

CTC ACG GTC CAG TTG ATT GTT GAG TTT GCT AAA GGT CTA CCA GCG TTT  
1056  
Leu Thr Val Gln Leu Ile Val Glu Phe Ala Lys Gly Leu Pro Ala Phe  
340 345 350

ACA AAG ATA CCC CAG GAG GAC CAG ATC ACG TTA CTA AAG GCC TGC TCG  
1104  
Thr Lys Ile Pro Gln Glu Asp Gln Ile Thr Leu Leu Lys Ala Cys Ser  
355 360 365

60

TCG GAG GTG ATG ATG CTG CGT ATG GCA CGA CGC TAT GAC CAC AGC TCG  
1152  
Ser Glu Val Met Met Leu Arg Met Ala Arg Arg Tyr Asp His Ser Ser

370 375 380

GAC TCA ATA TTC TTC GCG AAT AAT AGA TCA TAT ACG CGG GAT TCT TAC  
1200  
Asp Ser Ile Phe Phe Ala Asn Asn Arg Ser Tyr Thr Arg Asp Ser Tyr  
385 390 395 400

AAA ATG GCC GGA ATG GCT GAT AAC ATT GAA GAC CTG CTG CAT TTC TGC  
1248  
Lys Met Ala Gly Met Ala Asp Asn Ile Glu Asp Leu Leu His Phe Cys

405 410 415

CGC CAA ATG TTC TCG ATG AAG GTG GAC AAC GTC GAA TAC GCG CTT CTC  
1296  
Arg Gln Met Phe Ser Met Lys Val Asp Asn Val Glu Tyr Ala Leu Leu  
420 425 430

ACT GCC ATT GTG ATC TTC TCG GAC CGG CCG GGC CTG GAG AAG GCC CAA  
1344  
Thr Ala Ile Val Ile Phe Ser Asp Arg Pro Gly Leu Glu Lys Ala Gln

435 440 445

CTA GTC GAA GCG ATC CAG AGC TAC TAC ATC GAC ACG CTA CGC ATT TAT  
1392  
Leu Val Glu Ala Ile Gln Ser Tyr Tyr Ile Asp Thr Leu Arg Ile Tyr  
450 455 460

ATA CTC AAC CGC CAC TGC GGC GAC TCA ATG AGC CTC GTC TTC TAC GCA  
1440  
Ile Leu Asn Arg His Cys Gly Asp Ser Met Ser Leu Val Phe Tyr Ala  
465 470 475 480

AAG CTG CTC TCG ATC CTC ACC GAG CTG CGT ACG CTG GGC AAC CAG AAC  
1488  
Lys Leu Leu Ser Ile Leu Thr Glu Leu Arg Thr Leu Gly Asn Gln Asn

485 490 495

GCC GAG ATG TGT TTC TCA CTA AAG CTC AAA AAC CGC AAA CTG CCC AAG  
1536  
Ala Glu Met Cys Phe Ser Leu Lys Leu Lys Asn Arg Lys Leu Pro Lys

500

505

510

TTC CTC GAG GAG ATC TGG GAC GTT CAT GCC ATC CCG CCA TCG GTC CAG  
1584  
Phe Leu Glu Glu Ile Trp Asp Val His Ala Ile Pro Pro Ser Val Gln

515

520

525

TCG CAC CTT CAG ATT ACC CAG GAG GAG AAC GAG CGT CTC GAG CGG GCT  
1632  
Ser His Leu Gln Ile Thr Gln Glu Glu Asn Glu Arg Leu Glu Arg Ala

530

535

540

GAG CGT ATG CGG GCA TCG GTT GGG GGC GCC ATT ACC GCC GGC ATT GAT  
1680  
Glu Arg Met Arg Ala Ser Val Gly Gly Ala Ile Thr Ala Gly Ile Asp

545

550

555

560

TGC GAC TCT GCC TCC ACT TCG GCG GCG GCA GCC GCG GCC CAG CAT CAG  
1728  
Cys Asp Ser Ala Ser Thr Ser Ala Ala Ala Ala Ala Gln His Gln

565

570

575

CCT CAG CCT CAG CCC CAG CCC CAA CCC TCC TCC CTG ACC CAG AAC GAT  
1776  
Pro Gln Pro Gln Pro Gln Pro Ser Ser Leu Thr Gln Asn Asp

580

585

590

TCC CAG CAC CAG ACA CAG CCG CAG CTA CAA CCT CAG CTA CCA CCT CAG  
1824  
Ser Gln His Gln Thr Gln Pro Gln Leu Gln Pro Gln Leu Pro Pro Gln

595

600

605

CTG CAA GGT CAA CTG CAA CCC CAG CTC CAA CCA CAG CTT CAG ACG CAA  
1872  
Leu Gln Gly Gln Leu Gln Pro Gln Leu Gln Pro Gln Leu Gln Thr Gln

610

615

620

62

CTC CAG CCA CAG ATT CAA CCA CAG CCA CAG CTC CTT CCC GTC TCC GCT  
 1920

Leu Gln Pro Gln Ile Gln Pro Gln Pro Gln Leu Leu Pro Val Ser Ala

625                   630                   635                   640

CCC GTG CCC GCC TCC GTA ACC GCA CCT GGT TCC TTG TCC GCG GTC AGT  
 1968

Pro Val Pro Ala Ser Val Thr Ala Pro Gly Ser Leu Ser Ala Val Ser

645                   650                   655

ACG AGC AGC GAA TAC ATG GGC GGA AGT GCG GCC ATA GGA CCC ATC ACG  
 2016

Thr Ser Ser Glu Tyr Met Gly Ser Ala Ala Ile Gly Pro Ile Thr

660                   665                   670

CCG GCA ACC ACC AGC AGT ATC ACG GCT GCC GTT ACC GCT AGC TCC ACC  
 2064

Pro Ala Thr Thr Ser Ser Ile Thr Ala Ala Val Thr Ala Ser Ser Thr

675                   680                   685

ACA TCA GCG GTA CCG ATG GGC AAC GGA GTT GGA GTC GGT GTT GGG GTG  
 2112

Thr Ser Ala Val Pro Met Gly Asn Gly Val Gly Val Gly Val Gly Val

690                   695                   700

GGC GGC AAC GTC AGC ATG TAT GCG AAC GCC CAG ACG GCG ATG GCC TTG  
 2160

Gly Gly Asn Val Ser Met Tyr Ala Asn Ala Gln Thr Ala Met Ala Leu

705                   710                   715                   720

ATG GGT GTA GCC CTG CAT TCG CAC CAA GAG CAG CTT ATC GGG GGA GTG  
 2208

Met Gly Val Ala Leu His Ser His Gln Glu Gln Leu Ile Gly Gly Val

725                   730                   735

GCG GTT AAG TCG GAG CAC TCG ACG ACT GCA TAG  
 2241

Ala Val Lys Ser Glu His Ser Thr Thr Ala

740                   745

(2) INFORMATION FOR SEQ ID NO:7:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 746 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

Met	Ala	Pro	Pro	Thr	Asp	Val	Ser	Leu	Gly	Asp	Glu	Leu	His	Leu	Asp
1															15

Gly	Glu	Asp	Val	Ala	Met	Ala	His	Ala	Asp	Ala	Leu	Asp	Asp	Phe	Asp
															30
															20
															25

Leu	Asp	Met	Leu	Gly	Asp	Gly	Asp	Ser	Pro	Gly	Pro	Gly	Phe	Thr	Pro
															45
															35
															40

His	Asp	Ser	Ala	Pro	Tyr	Gly	Ala	Leu	Asp	Met	Ala	Asp	Phe	Glu	Phe
															60
															50
															55

Glu	Gln	Met	Phe	Thr	Asp	Ala	Leu	Gly	Ile	Asp	Glu	Tyr	Gly	Gly	Lys
															80
															65
															70

Leu	Leu	Gly	Thr	Ser	Arg	Arg	Ile	Ser	Asn	Ser	Ile	Ser	Ser	Gly	Arg
															95
															85
															90

Asp	Asp	Leu	Ser	Pro	Ser	Ser	Leu	Asn	Gly	Tyr	Ser	Ala	Asn	Glu	
															110
															100
															105

Ser	Cys	Asp	Ala	Lys	Lys	Ser	Lys	Lys	Gly	Pro	Ala	Pro	Arg	Val	Gln
															125
															115
															120

Glu	Glu	Leu	Cys	Leu	Val	Cys	Gly	Asp	Arg	Ala	Ser	Gly	Tyr	His	Tyr
															140
															130
															135

Asn	Ala	Leu	Thr	Cys	Glu	Gly	Cys	Lys	Gly	Phe	Phe	Arg	Arg	Ser	Val
															160
															145
															150

Thr	Lys	Ser	Ala	Val	Tyr	Cys	Cys	Lys	Phe	Gly	Arg	Ala	Cys	Glu	Met
															175
															165
															170

Asp	Met	Tyr	Met	Arg	Arg	Lys	Cys	Gln	Glu	Cys	Arg	Leu	Lys	Lys	Cys
															190
															180
															185

Leu Ala Val Gly Met Arg Pro Glu Cys Val Val Pro Glu Asn Gln Cys

195

200

205

Ala Met Lys Arg Arg Glu Lys Lys Ala Gln Lys Glu Lys Asp Lys Met  
210 215 220

Thr Thr Ser Pro Ser Ser Gln His Gly Gly Asn Gly Ser Leu Ala Ser  
225 230 235 240

Gly Gly Gly Gln Asp Phe Val Lys Lys Glu Ile Leu Asp Leu Met Thr  
245 250 255

Cys Glu Pro Pro Gln His Ala Thr Ile Pro Leu Leu Pro Asp Glu Ile  
260 265 270

Leu Ala Lys Cys Gln Ala Arg Asn Ile Pro Ser Leu Thr Tyr Asn Gln  
275 280 285

Leu Ala Val Ile Tyr Lys Leu Ile Trp Tyr Gln Asp Gly Tyr Glu Gln  
290 295 300

Pro Ser Glu Glu Asp Leu Arg Arg Ile Met Ser Gln Pro Asp Glu Asn  
305 310 315 320

Glu Ser Gln Thr Asp Val Ser Phe Arg His Ile Thr Glu Ile Thr Ile  
325 330 335

Leu Thr Val Gln Leu Ile Val Glu Phe Ala Lys Gly Leu Pro Ala Phe  
340 345 350

Thr Lys Ile Pro Gln Glu Asp Gln Ile Thr Leu Leu Lys Ala Cys Ser  
355 360 365

Ser Glu Val Met Met Leu Arg Met Ala Arg Arg Tyr Asp His Ser Ser  
370 375 380

Asp Ser Ile Phe Phe Ala Asn Asn Arg Ser Tyr Thr Arg Asp Ser Tyr  
385 390 395 400

Lys Met Ala Gly Met Ala Asp Asn Ile Glu Asp Leu Leu His Phe Cys  
405 410 415

Arg Gln Met Phe Ser Met Lys Val Asp Asn Val Glu Tyr Ala Leu Leu  
420 425 430

65

Thr Ala Ile Val Ile Phe Ser Asp Arg Pro Gly Leu Glu Lys Ala Gln  
435 440 445

Leu Val Glu Ala Ile Gln Ser Tyr Tyr Ile Asp Thr Leu Arg Ile Tyr  
450 455 460

Ile Leu Asn Arg His Cys Gly Asp Ser Met Ser Leu Val Phe Tyr Ala  
465 470 475 480

Lys Leu Leu Ser Ile Leu Thr Glu Leu Arg Thr Leu Gly Asn Gln Asn  
485 490 495

Ala Glu Met Cys Phe Ser Leu Lys Leu Lys Asn Arg Lys Leu Pro Lys  
500 505 510

Phe Leu Glu Glu Ile Trp Asp Val His Ala Ile Pro Pro Ser Val Gln  
515 520 525

Ser His Leu Gln Ile Thr Gln Glu Glu Asn Glu Arg Leu Glu Arg Ala  
530 535 540

Glu Arg Met Arg Ala Ser Val Gly Gly Ala Ile Thr Ala Gly Ile Asp  
545 550 555 560

Cys Asp Ser Ala Ser Thr Ser Ala Ala Ala Ala Ala Gln His Gln  
565 570 575

Pro Gln Pro Gln Pro Gln Pro Gln Pro Ser Ser Leu Thr Gln Asn Asp  
580 585 590

Ser Gln His Gln Thr Gln Pro Gln Leu Gln Pro Gln Leu Pro Pro Gln  
595 600 605

Leu Gln Gly Gln Leu Gln Pro Gln Leu Gln Pro Gln Leu Gln Thr Gln  
610 615 620

Leu Gln Pro Gln Ile Gln Pro Gln Pro Gln Leu Leu Pro Val Ser Ala  
625 630 635 640

Pro Val Pro Ala Ser Val Thr Ala Pro Gly Ser Leu Ser Ala Val Ser  
645 650 655

Thr Ser Ser Glu Tyr Met Gly Gly Ser Ala Ala Ile Gly Pro Ile Thr

66

660

665

670

Pro Ala Thr Thr Ser Ser Ile Thr Ala Ala Val Thr Ala Ser Ser Thr  
675                       680                       685

Thr Ser Ala Val Pro Met Gly Asn Gly Val Gly Val Gly Val Gly Val  
690                       695                       700

Gly Gly Asn Val Ser Met Tyr Ala Asn Ala Gln Thr Ala Met Ala Leu  
705                       710                       715                       720

Met Gly Val Ala Leu His Ser His Gln Glu Gln Leu Ile Gly Gly Val  
725                       730                       735

Ala Val Lys Ser Glu His Ser Thr Thr Ala  
740                       745

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 3126 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: both  
(D) TOPOLOGY: both

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:  
(A) NAME/KEY: CDS  
(B) LOCATION: 1..3126  
(D) OTHER INFORMATION: /product= "GEcR"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

ATG GAC TCC AAA GAA TCA TTA ACT CCT GGT AGA GAA GAA AAC CCC AGC  
48  
Met Asp Ser Lys Glu Ser Leu Thr Pro Gly Arg Glu Glu Asn Pro Ser

1

5

10

15

AGT GTG CTT GCT CAG GAG AGG GGA GAT GTG ATG GAC TTC TAT AAA ACC  
96  
Ser Val Leu Ala Gln Glu Arg Gly Asp Val Met Asp Phe Tyr Lys Thr

20

25

30

CTA AGA GGA GGA GCT ACT GTG AAG GTT TCT GCG TCT TCA CCC TCA CTG  
144  
Leu Arg Gly Gly Ala Thr Val Lys Val Ser Ala Ser Ser Pro Ser Leu  
35 40 45

GCT GTC GCT TCT CAA TCA GAC TCC AAG CAG CGA AGA CTT TTG GTT GAT  
192  
Ala Val Ala Ser Gln Ser Asp Ser Lys Gln Arg Arg Leu Leu Val Asp  
50 55 60

TTT CCA AAA GGC TCA GTA AGC AAT GCG CAG CAG CCA GAT CTG TCC AAA  
240  
Phe Pro Lys Gly Ser Val Ser Asn Ala Gln Gln Pro Asp Leu Ser Lys  
65 70 75 80

GCA GTT TCA CTC TCA ATG GGA CTG TAT ATG GGA GAG ACA GAA ACA AAA  
288  
Ala Val Ser Leu Ser Met Gly Leu Tyr Met Gly Glu Thr Glu Thr Lys  
85 90 95

GTG ATG GGA AAT GAC CTG GGA TTC CCA CAG CAG GGC CAA ATC AGC CTT  
336  
Val Met Gly Asn Asp Leu Gly Phe Pro Gln Gln Gly Gln Ile Ser Leu  
100 105 110

TCC TCG GGG GAA ACA GAC TTA AAG CTT TTG GAA GAA AGC ATT GCA AAC  
384  
Ser Ser Gly Glu Thr Asp Leu Lys Leu Leu Glu Glu Ser Ile Ala Asn  
115 120 125

CTC AAT AGG TCG ACC AGT GTT CCA GAG AAC CCC AAG AGT TCA GCA TCC  
432  
Leu Asn Arg Ser Thr Ser Val Pro Glu Asn Pro Lys Ser Ser Ala Ser  
130 135 140

ACT GCT GTG TCT GCT GCC CCC ACA GAG AAG GAG TTT CCA AAA ACT CAC  
480  
Thr Ala Val Ser Ala Ala Pro Thr Glu Lys Glu Phe Pro Lys Thr His  
145 150 155 160

TCT GAT GTA TCT TCA GAA CAG CAA CAT TTG AAG GGC CAG ACT GGC ACC  
528  
Ser Asp Val Ser Ser Glu Gln Gln His Leu Lys Gly Gln Thr Gly Thr

165 170 175

AAC GGT GGC AAT GTG AAA TTG TAT ACC ACA GAC CAA AGC ACC TTT GAC  
576  
Asn Gly Gly Asn Val Lys Leu Tyr Thr Thr Asp Gln Ser Thr Phe Asp

180 185 190

ATT TTG CAG GAT TTG GAG TTT TCT TCT GGG TCC CCA GGT AAA GAG ACG  
624  
Ile Leu Gln Asp Leu Glu Phe Ser Ser Gly Ser Pro Gly Lys Glu Thr

195 200 205

AAT GAG AGT CCT TGG AGA TCA GAC CTG TTG ATA GAT GAA AAC TGT TTG  
672  
Asn Glu Ser Pro Trp Arg Ser Asp Leu Leu Ile Asp Glu Asn Cys Leu

210 215 220

CTT TCT CCT CTG GCG GGA GAA GAC GAT TCA TTC CTT TTG GAA GGA AAC  
720  
Leu Ser Pro Leu Ala Gly Glu Asp Asp Ser Phe Leu Leu Glu Gly Asn  
225 230 235 240

TCG AAT GAG GAC TGC AAG CCT CTC ATT TTA CCG GAC ACT AAA CCC AAA  
768  
Ser Asn Glu Asp Cys Lys Pro Leu Ile Leu Pro Asp Thr Lys Pro Lys

245 250 255

ATT AAG GAT AAT GGA GAT CTG GTT TTG TCA AGC CCC AGT AAT GTA ACA  
816  
Ile Lys Asp Asn Gly Asp Leu Val Leu Ser Ser Pro Ser Asn Val Thr  
260 265 270

CTG CCC CAA GTG AAA ACA GAA AAA GAA GAT TTC ATC GAA CTC TGC ACC  
864  
Leu Pro Gln Val Lys Thr Glu Lys Glu Asp Phe Ile Glu Leu Cys Thr

275 280 285

69

CCT GGG GTA ATT AAG CAA GAG AAA CTG GGC ACA GTT TAC TGT CAG GCA  
912  
Pro Gly Val Ile Lys Gln Glu Lys Leu Gly Thr Val Tyr Cys Gln Ala

290 295 300

AGC TTT CCT GGA GCA AAT ATA ATT GGT AAT AAA ATG TCT GCC ATT TCT  
960  
Ser Phe Pro Gly Ala Asn Ile Ile Gly Asn Lys Met Ser Ala Ile Ser  
305 310 315 320

GTT CAT GGT GTG AGT ACC TCT GGA GGA CAG ATG TAC CAC TAT GAC ATG  
1008  
Val His Gly Val Ser Thr Ser Gly Gly Gln Met Tyr His Tyr Asp Met  
325 330 335

AAT ACA GCA TCC CTT TCT CAA CAG CAG GAT CAG AAG CCT ATT TTT AAT  
1056  
Asn Thr Ala Ser Leu Ser Gln Gln Asp Gln Lys Pro Ile Phe Asn  
340 345 350

GTC ATT CCA CCA ATT CCC GTT GGT TCC GAA AAT TGG AAT AGG TGC CAA  
1104  
Val Ile Pro Pro Ile Pro Val Gly Ser Glu Asn Trp Asn Arg Cys Gln  
355 360 365

GGA TCT GGA GAT GAC AAC TTG ACT TCT CTG GGG ACT CTG AAC TTC CCT  
1152  
Gly Ser Gly Asp Asp Asn Leu Thr Ser Leu Gly Thr Leu Asn Phe Pro  
370 375 380

GGT CGA ACA GTT TTT TCT AAT GGC TAT TCA AGC CCC AGC ATG AGA CCA  
1200  
Gly Arg Thr Val Phe Ser Asn Gly Tyr Ser Ser Pro Ser Met Arg Pro  
385 390 395 400

GAT GTA AGC TCT CCT CCA TCC AGC TCC TCA ACA GCA ACA ACA GGA CCA  
1248  
Asp Val Ser Ser Pro Pro Ser Ser Ser Thr Ala Thr Thr Gly Pro  
405 410 415

CCT CCC AGC GGC CGC GTG CAA GAG GAG CTG TGC CTG GTT TGC GGC GAC  
 1296  
 Pro Pro Ser Gly Arg Val Gln Glu Glu Leu Cys Leu Val Cys Gly Asp

420 425 430

AGG GCC TCC GGC TAC CAC TAC AAC GCC CTC ACC TGT GGA TCC TGC AAG  
 1344  
 Arg Ala Ser Gly Tyr His Tyr Asn Ala Leu Thr Cys Gly Ser Cys Lys

435 440 445

GTG TTC TTT CGA CGC AGC GTT ACG AAG AGC GCC GTC TAC TGC TGC AAG  
 1392  
 Val Phe Phe Arg Arg Ser Val Thr Lys Ser Ala Val Tyr Cys Cys Lys

450 455 460

TTC GGG CGC GCC TGC GAA ATG GAC ATG TAC ATG AGG CGA AAG TGT CAG  
 1440  
 Phe Gly Arg Ala Cys Glu Met Asp Met Tyr Met Arg Arg Lys Cys Gln

465 470 475 480

GAG TGC CGC CTG AAA AAG TGC CTG GCC GTG GGT ATG CGG CCG GAA TGC  
 1488  
 Glu Cys Arg Leu Lys Lys Cys Leu Ala Val Gly Met Arg Pro Glu Cys

485 490 495

GTC GTC CCG GAG AAC CAA TGT GCG ATG AAG CGG CGC GAA AAG AAG GCC  
 1536  
 Val Val Pro Glu Asn Gln Cys Ala Met Lys Arg Arg Glu Lys Lys Ala

500 505 510

CAG AAG GAG AAG GAC AAA ATG ACC ACT TCG CCG AGC TCT CAG CAT GGC  
 1584  
 Gln Lys Glu Lys Asp Lys Met Thr Thr Ser Pro Ser Ser Gln His Gly

515 520 525

GGC AAT GGC AGC TTG GCC TCT GGT GGC GGC CAA GAC TTT GTT AAG AAG  
 1632  
 Gly Asn Gly Ser Leu Ala Ser Gly Gly Gln Asp Phe Val Lys Lys

530 535 540

GAG ATT CTT GAC CTT ATG ACA TGC GAG CCG CCC CAG CAT GCC ACT ATT  
 1680  
 Glu Ile Leu Asp Leu Met Thr Cys Glu Pro Pro Gln His Ala Thr Ile  
 545                550                555                560

CCG CTA CTA CCT GAT GAA ATA TTG GCC AAG TGT CAA GCG CGC AAT ATA  
 1728  
 Pro Leu Leu Pro Asp Glu Ile Leu Ala Lys Cys Gln Ala Arg Asn Ile  
 565                570                575

CCT TCC TTA ACG TAC AAT CAG TTG GCC GTT ATA TAC AAG TTA ATT TGG  
 1776  
 Pro Ser Leu Thr Tyr Asn Gln Leu Ala Val Ile Tyr Lys Leu Ile Trp  
 580                585                590

TAC CAG GAT GGC TAT GAG CAG CCA TCT GAA GAG GAT CTC AGG CGT ATA  
 1824  
 Tyr Gln Asp Gly Tyr Glu Gln Pro Ser Glu Glu Asp Leu Arg Arg Ile  
 595                600                605

ATG AGT CAA CCC GAT GAG AAC GAG AGC CAA ACG GAC GTC AGC TTT CGG  
 1872  
 Met Ser Gln Pro Asp Glu Asn Glu Ser Gln Thr Asp Val Ser Phe Arg  
 610                615                620

CAT ATA ACC GAG ATA ACC ATA CTC ACG GTC CAG TTG ATT GTT GAG TTT  
 1920  
 His Ile Thr Glu Ile Thr Ile Leu Thr Val Gln Leu Ile Val Glu Phe  
 625                630                635                640

GCT AAA GGT CTA CCA GCG TTT ACA AAG ATA CCC CAG GAG GAC CAG ATC  
 1968  
 Ala Lys Gly Leu Pro Ala Phe Thr Lys Ile Pro Gln Glu Asp Gln Ile  
 645                650                655

ACG TTA CTA AAG GCC TGC TCG TCG GAG GTG ATG ATG CTG CGT ATG GCA  
 2016  
 Thr Leu Leu Lys Ala Cys Ser Ser Glu Val Met Met Leu Arg Met Ala  
 660                665                670

CGA CGC TAT GAC CAC AGC TCG GAC TCA ATA TTC TTC GCG AAT AAT AGA  
 2064  
 Arg Arg Tyr Asp His Ser Ser Asp Ser Ile Phe Phe Ala Asn Asn Arg

675                    680                    685

TCA TAT ACG CGG GAT TCT TAC AAA ATG GCC GGA ATG GCT GAT AAC ATT  
 2112  
 Ser Tyr Thr Arg Asp Ser Tyr Lys Met Ala Gly Met Ala Asp Asn Ile  
 690                    695                    700

GAA GAC CTG CTG CAT TTC TGC CGC CAA ATG TTC TCG ATG AAG GTG GAC  
 2160  
 Glu Asp Leu Leu His Phe Cys Arg Gln Met Phe Ser Met Lys Val Asp  
 705                    710                    715                    720

AAC GTC GAA TAC GCG CTT CTC ACT GCC ATT GTG ATC TTC TCG GAC CGG  
 2208  
 Asn Val Glu Tyr Ala Leu Leu Thr Ala Ile Val Ile Phe Ser Asp Arg  
 725                    730                    735

CCG GGC CTG GAG AAG GCC CAA CTA GTC GAA GCG ATC CAG AGC TAC TAC  
 2256  
 Pro Gly Leu Glu Lys Ala Gln Leu Val Glu Ala Ile Gln Ser Tyr Tyr  
 740                    745                    750

ATC GAC ACG CTA CGC ATT TAT ATA CTC AAC CGC CAC TGC GGC GAC TCA  
 2304  
 Ile Asp Thr Leu Arg Ile Tyr Ile Leu Asn Arg His Cys Gly Asp Ser  
 755                    760                    765

ATG AGC CTC GTC TTC TAC GCA AAG CTG CTC TCG ATC CTC ACC GAG CTG  
 2352  
 Met Ser Leu Val Phe Tyr Ala Lys Leu Leu Ser Ile Leu Thr Glu Leu  
 770                    775                    780

CGT ACG CTG GGC AAC CAG AAC GGC GAG ATG TGT TTC TCA CTA AAG CTC  
 2400  
 Arg Thr Leu Gly Asn Gln Asn Ala Glu Met Cys Phe Ser Leu Lys Leu  
 785                    790                    795                    800

AAA AAC CGC AAA CTG CCC AAG TTC CTC GAG GAG ATC TGG GAC GTT CAT  
2448  
Lys Asn Arg Lys Leu Pro Lys Phe Leu Glu Glu Ile Trp Asp Val His  
805 810 815

GCC ATC CCG CCA TCG GTC CAG TCG CAC CTT CAG ATT ACC CAG GAG GAG  
2496  
Ala Ile Pro Pro Ser Val Gln Ser His Leu Gln Ile Thr Gln Glu Glu  
820 825 830

AAC GAG CGT CTC GAG CGG GCT GAG CGT ATG CGG GCA TCG GTT GGG GGC  
2544  
Asn Glu Arg Leu Glu Arg Ala Glu Arg Met Arg Ala Ser Val Gly Gly  
835 840 845

GCC ATT ACC GCC GGC ATT GAT TGC GAC TCT GCC TCC ACT TCG GCG GCG  
2592  
Ala Ile Thr Ala Gly Ile Asp Cys Asp Ser Ala Ser Thr Ser Ala Ala  
850 855 860

GCA GCC GCG GCC CAG CAT CAG CCT CAG CCT CAG CCC CAG CCC CAA CCC  
2640  
Ala Ala Ala Ala Gln His Gln Pro Gln Pro Gln Pro Gln Pro  
865 870 875 880

TCC TCC CTG ACC CAG AAC GAT TCC CAG CAC CAG ACA CAG CCG CAG CTA  
2688  
Ser Ser Leu Thr Gln Asn Asp Ser Gln His Gln Thr Gln Pro Gln Leu  
885 890 895

CAA CCT CAG CTA CCA CCT CAG CTG CAA GGT CAA CTG CAA CCC CAG CTC  
2736  
Gln Pro Gln Leu Pro Pro Gln Leu Gln Gly Gln Leu Gln Pro Gln Leu  
900 905 910

CAA CCA CAG CTT CAG ACG CAA CTC CAG CCA CAG ATT CAA CCA CAG CCA  
2784  
Gln Pro Gln Leu Gln Thr Gln Leu Gln Pro Gln Ile Gln Pro Gln Pro  
915 920 925

CAG CTC CTT CCC GTC TCC GCT CCC GTG CCC GCC TCC GTA ACC GCA CCT  
2832  
Gln Leu Leu Pro Val Ser Ala Pro Val Pro Ala Ser Val Thr Ala Pro  
930 935 940

GGT TCC TTG TCC GCG GTC AGT ACG AGC AGC GAA TAC ATG GGC GGA AGT  
2880  
Gly Ser Leu Ser Ala Val Ser Thr Ser Ser Glu Tyr Met Gly Gly Ser  
945 950 955 960

GCG GCC ATA GGA CCC ATC ACG CCG GCA ACC ACC AGC AGT ATC ACG GCT  
2928  
Ala Ala Ile Gly Pro Ile Thr Pro Ala Thr Thr Ser Ser Ile Thr Ala  
965 970 975

GCC GTT ACC GCT AGC TCC ACC ACA TCA GCG GTA CCG ATG GGC AAC GGA  
2976  
Ala Val Thr Ala Ser Ser Thr Thr Ser Ala Val Pro Met Gly Asn Gly  
980 985 990

GTT GGA GTC GGT GTT GGG GTG GGC GGC AAC GTC AGC ATG TAT GCG AAC  
3024  
Val Gly Val Gly Val Gly Gly Asn Val Ser Met Tyr Ala Asn  
995 1000 1005

GCC CAG ACG GCG ATG GCC TTG ATG GGT GTA GCC CTG CAT TCG CAC CAA  
3072  
Ala Gln Thr Ala Met Ala Leu Met Gly Val Ala Leu His Ser His Gln  
1010 1015 1020

GAG CAG CTT ATC GGG GGA GTG GCG GTT AAG TCG GAG CAC TCG ACG ACT  
3120  
Glu Gln Leu Ile Gly Gly Val Ala Val Lys Ser Glu His Ser Thr Thr  
1025 1030 1035 1040

GCA TAG  
3126  
Ala

(2) INFORMATION FOR SEQ ID NO:9:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1041 amino acids
- (B) TYPE: amino acid
- (C) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

Met Asp Ser Lys Glu Ser Leu Thr Pro Gly Arg Glu Glu Asn Pro Ser  
1 5 10 15

Ser Val Leu Ala Gln Glu Arg Gly Asp Val Met Asp Phe Tyr Lys Thr  
20 25 30

Leu Arg Gly Gly Ala Thr Val Lys Val Ser Ala Ser Ser Pro Ser Leu  
35 40 45

Ala Val Ala Ser Gln Ser Asp Ser Lys Gln Arg Arg Leu Leu Val Asp  
50 55 60

Phe Pro Lys Gly Ser Val Ser Asn Ala Gln Gln Pro Asp Leu Ser Lys  
65 70 75 80

Ala Val Ser Leu Ser Met Gly Leu Tyr Met Gly Glu Thr Glu Thr Lys  
85 90 95

Val Met Gly Asn Asp Leu Gly Phe Pro Gln Gln Gly Gln Ile Ser Leu  
100 105 110

Ser Ser Gly Glu Thr Asp Leu Lys Leu Leu Glu Glu Ser Ile Ala Asn  
115 120 125

Leu Asn Arg Ser Thr Ser Val Pro Glu Asn Pro Lys Ser Ser Ala Ser  
130 135 140

Thr Ala Val Ser Ala Ala Pro Thr Glu Lys Glu Phe Pro Lys Thr His  
145 150 155 160

Ser Asp Val Ser Ser Glu Gln Gln His Leu Lys Gly Gln Thr Gly Thr  
165 170 175

Asn Gly Gly Asn Val Lys Leu Tyr Thr Thr Asp Gln Ser Thr Phe Asp  
180 185 190

Ile Leu Gln Asp Leu Glu Phe Ser Ser Gly Ser Pro Gly Lys Glu Thr

195

200

205

Asn Glu Ser Pro Trp Arg Ser Asp Leu Leu Ile Asp Glu Asn Cys Leu  
210                   215                   220

Leu Ser Pro Leu Ala Gly Glu Asp Asp Ser Phe Leu Leu Glu Gly Asn  
225                   230                   235                   240

Ser Asn Glu Asp Cys Lys Pro Leu Ile Leu Pro Asp Thr Lys Pro Lys  
245                   250                   255

Ile Lys Asp Asn Gly Asp Leu Val Leu Ser Ser Pro Ser Asn Val Thr  
260                   265                   270

Leu Pro Gln Val Lys Thr Glu Lys Glu Asp Phe Ile Glu Leu Cys Thr  
275                   280                   285

Pro Gly Val Ile Lys Gln Glu Lys Leu Gly Thr Val Tyr Cys Gln Ala  
290                   295                   300

Ser Phe Pro Gly Ala Asn Ile Ile Gly Asn Lys Met Ser Ala Ile Ser  
305                   310                   315                   320

Val His Gly Val Ser Thr Ser Gly Gly Gln Met Tyr His Tyr Asp Met  
325                   330                   335

Asn Thr Ala Ser Leu Ser Gln Gln Asp Gln Lys Pro Ile Phe Asn  
340                   345                   350

Val Ile Pro Pro Ile Pro Val Gly Ser Glu Asn Trp Asn Arg Cys Gln  
355                   360                   365

Gly Ser Gly Asp Asp Asn Leu Thr Ser Leu Gly Thr Leu Asn Phe Pro  
370                   375                   380

Gly Arg Thr Val Phe Ser Asn Gly Tyr Ser Ser Pro Ser Met Arg Pro  
385                   390                   395                   400

Asp Val Ser Ser Pro Pro Ser Ser Ser Thr Ala Thr Thr Gly Pro  
405                   410                   415

Pro Pro Ser Gly Arg Val Gln Glu Glu Leu Cys Leu Val Cys Gly Asp  
420                   425                   430

Arg Ala Ser Gly Tyr His Tyr Asn Ala Leu Thr Cys Gly Ser Cys Lys  
435 440 445

Val Phe Phe Arg Arg Ser Val Thr Lys Ser Ala Val Tyr Cys Cys Lys  
450 455 460

Phe Gly Arg Ala Cys Glu Met Asp Met Tyr Met Arg Arg Lys Cys Gln  
465 470 475 480

Glu Cys Arg Leu Lys Lys Cys Leu Ala Val Gly Met Arg Pro Glu Cys  
485 490 495

Val Val Pro Glu Asn Gln Cys Ala Met Lys Arg Arg Glu Lys Lys Ala  
500 505 510

Gln Lys Glu Lys Asp Lys Met Thr Thr Ser Pro Ser Ser Gln His Gly  
515 520 525

Gly Asn Gly Ser Leu Ala Ser Gly Gly Gln Asp Phe Val Lys Lys  
530 535 540

Glu Ile Leu Asp Leu Met Thr Cys Glu Pro Pro Gln His Ala Thr Ile  
545 550 555 560

Pro Leu Leu Pro Asp Glu Ile Leu Ala Lys Cys Gln Ala Arg Asn Ile  
565 570 575

Pro Ser Leu Thr Tyr Asn Gln Leu Ala Val Ile Tyr Lys Leu Ile Trp  
580 585 590

Tyr Gln Asp Gly Tyr Glu Gln Pro Ser Glu Glu Asp Leu Arg Arg Ile  
595 600 605

Met Ser Gln Pro Asp Glu Asn Glu Ser Gln Thr Asp Val Ser Phe Arg  
610 615 620

His Ile Thr Glu Ile Thr Ile Leu Thr Val Gln Leu Ile Val Glu Phe  
625 630 635 640

Ala Lys Gly Leu Pro Ala Phe Thr Lys Ile Pro Gln Glu Asp Gln Ile  
645 650 655

Thr Leu Leu Lys Ala Cys Ser Ser Glu Val Met Met Leu Arg Met Ala  
660 665 670

Arg Arg Tyr Asp His Ser Ser Asp Ser Ile Phe Phe Ala Asn Asn Arg  
 675 680 685  
 Ser Tyr Thr Arg Asp Ser Tyr Lys Met Ala Gly Met Ala Asp Asn Ile  
 690 695 700  
 Glu Asp Leu Leu His Phe Cys Arg Gln Met Phe Ser Met Lys Val Asp  
 705 710 715 720  
 Asn Val Glu Tyr Ala Leu Leu Thr Ala Ile Val Ile Phe Ser Asp Arg  
 725 730 735  
 Pro Gly Leu Glu Lys Ala Gln Leu Val Glu Ala Ile Gln Ser Tyr Tyr  
 740 745 750  
 Ile Asp Thr Leu Arg Ile Tyr Ile Leu Asn Arg His Cys Gly Asp Ser  
 755 760 765  
 Met Ser Leu Val Phe Tyr Ala Lys Leu Leu Ser Ile Leu Thr Glu Leu  
 770 775 780  
 Arg Thr Leu Gly Asn Gln Asn Ala Glu Met Cys Phe Ser Leu Lys Leu  
 785 790 795 800  
 Lys Asn Arg Lys Leu Pro Lys Phe Leu Glu Glu Ile Trp Asp Val His  
 805 810 815  
 Ala Ile Pro Pro Ser Val Gln Ser His Leu Gln Ile Thr Gln Glu Glu  
 820 825 830  
 Asn Glu Arg Leu Glu Arg Ala Glu Arg Met Arg Ala Ser Val Gly Gly  
 835 840 845  
 Ala Ile Thr Ala Gly Ile Asp Cys Asp Ser Ala Ser Thr Ser Ala Ala  
 850 855 860  
 Ala Ala Ala Ala Gln His Gln Pro Gln Pro Gln Pro Gln Pro  
 865 870 875 880  
 Ser Ser Leu Thr Gln Asn Asp Ser Gln His Gln Thr Gln Pro Gln Leu  
 885 890 895  
 Gln Pro Gln Leu Pro Pro Gln Leu Gln Gly Gln Leu Gln Pro Gln Leu

79

900

905

910

Gln Pro Gln Leu Gln Thr Gln Leu Gln Pro Gln Ile Gln Pro Gln Pro  
915 920 925

Gln Leu Leu Pro Val Ser Ala Pro Val Pro Ala Ser Val Thr Ala Pro  
930 935 940

Gly Ser Leu Ser Ala Val Ser Thr Ser Ser Glu Tyr Met Gly Gly Ser  
945 950 955 960

Ala Ala Ile Gly Pro Ile Thr Pro Ala Thr Thr Ser Ser Ile Thr Ala  
965 970 975

Ala Val Thr Ala Ser Ser Thr Thr Ser Ala Val Pro Met Gly Asn Gly  
980 985 990

Val Gly Val Gly Val Gly Val Gly Gly Asn Val Ser Met Tyr Ala Asn  
995 1000 1005

Ala Gln Thr Ala Met Ala Leu Met Gly Val Ala Leu His Ser His Gln  
1010 1015 1020

Glu Gln Leu Ile Gly Gly Val Ala Val Lys Ser Glu His Ser Thr Thr  
1025 1030 1035 1040

Ala

(2) INFORMATION FOR SEO ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: both
- (D) TOPOLOGY: both

ii) MOLECULE TYPE: DNA (genomic)

## (ix) FEATURE:

- (A) NAME/KEY: misc\_feature
- (B) LOCATION: 7
- (D) OTHER INFORMATION: /product= "Modified Ecdysone Response Element"  
/note= "N at position 7 is 0 up to 5 nucleotides,  
with 1 nucleotide being especially preferred."

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

RGBNNMNTGN NCY  
13

## (2) INFORMATION FOR SEQ ID NO:11:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: both
- (D) TOPOLOGY: both

## (ii) MOLECULE TYPE: DNA (genomic)

## (ix) FEATURE:

- (A) NAME/KEY: misc\_feature
- (B) LOCATION: 7
- (D) OTHER INFORMATION: /product= "Modified Ecdysone Response Element"  
/note= "N at position 7 can be 0 up to 5 nucleotides, with 1 nucleotide being preferred."

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

RGNNCANKNN VCY  
13

## (2) INFORMATION FOR SEQ ID NO:12:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: both
- (D) TOPOLOGY: both

## (ii) MOLECULE TYPE: DNA (genomic)

## (xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

AGTGCANTGT TCT  
13

## (2) INFORMATION FOR SEQ ID NO:13:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 13 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: both
- (D) TOPOLOGY: both

(ii) MOLECULE TYPE: DNA (genomic)

## (ix) FEATURE:

- (A) NAME/KEY: misc\_feature
- (B) LOCATION: 7
- (D) OTHER INFORMATION: /product= "Ecdysone Response Element"  
/note= "N at position 7 can be 0 up to 5  
nucleotides, with 3 nucleotides being  
preferred."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

RGBNNMNRGB NNM  
13

## (2) INFORMATION FOR SEQ ID NO:14:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 49 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: both
- (D) TOPOLOGY: both

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

TACAACGCC C TCACCTGTGG ATCCTGCAAG GTGTTTCTTT CGACGCAGC  
49

## (2) INFORMATION FOR SEQ ID NO:15:

## (i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 53 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: both
- (D) TOPOLOGY: both

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

GTACTCCGG GGCGGGGCTA TGCAGGGCGG GGCTAACCGC TAGGGCGGG GCA  
53

## (2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:  
(A) LENGTH: 53 base pairs  
(B) TYPE: nucleic acid  
(C) STRANDEDNESS: both  
(D) TOPOLOGY: both

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

GTACTGCCCG GCCCCTAGCG ATTAGCCCCG CCCCCGCATAG CCCCCGCCCG GGA  
53

## (2) INFORMATION FOR SEQ ID NO:17:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 34 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: both
  - (D) TOPOLOGY: both

- (ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

AGCTCGATGG ACAAGTGCAT TGTTCTTGCG TGAA  
34

## (2) INFORMATION FOR SEQ ID NO:18:

- (i) SEQUENCE CHARACTERISTICS:
  - (A) LENGTH: 35 base pairs
  - (B) TYPE: nucleic acid
  - (C) STRANDEDNESS: both
  - (D) TOPOLOGY: both

- (ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

AGCTTTCAGC AAGAGAACAA TGCACTTGTC CATCG  
35

That which is claimed is:

1. A method for modulating the expression of an exogenous gene in a mammalian subject containing:

5 (i) a DNA construct comprising said exogenous gene under the control of an ecdysone response element; and

10 (ii) a modified ecdysone receptor which, in the presence of a ligand therefor, and optionally in the further presence of a receptor capable of acting as a silent partner therefor, binds to said modified ecdysone response element;

15 said method comprising administering to said subject an effective amount of a ligand for said modified ecdysone receptor; wherein said ligand is not normally present in the cells of said subject; and wherein said ligand is not toxic to said subject.

2. A method according to claim 1, wherein said ecdysone response element is a modified response element which comprises, in any order, a first half-site and a second half-site separated by a spacer of 0-5 nucleotides;

5 wherein said first half-site has the sequence:

-RGBNNM-,

wherein

10 each R is independently selected from A or G;  
each B is independently selected from G, C, or T;  
each N is independently selected from A, T, C, or  
G; and

each M is independently selected from A or C; with the proviso that at least 4 nucleotides of each 15 -RGBNNM- group of nucleotides are identical with the nucleotides at comparable positions of the sequence -AGGTCA-; and

said second half-site is obtained from a glucocorticoid receptor subfamily response element.

3. A method according to claim 2, wherein said first half-site is obtained from an ecdysone response element and said second half-site is obtained from a hormone response element selected from a glucocorticoid 5 response element, a mineralocorticoid response element, a progesterone response element or an androgen response element.

4. A method according to claim 2, wherein said response element has substantially no binding affinity for farnesoid X receptor (FXR).

5. A method according to claim 2, wherein said first half-site is obtained from an ecdysone response element and said second half-site is obtained from a glucocorticoid response element.

6. A method according to claim 5, wherein said first half-site is AGTGCA and said second half-site is TGTTCT.

7. A method according to claim 6, wherein said response element has the sequence AGTGCA-N-TGTTCT.

8. A method according to claim 2, wherein said modified ecdysone receptor comprises:

an ecdysone ligand binding domain;

5 a DNA-binding domain obtained from a DNA-binding protein; and

an activation domain of a transcription factor,

wherein at least one of said DNA-binding domain or said activation domain is not obtained  
10 from a native ecdysone receptor,

with the proviso that when said activation domain is derived from a glucocorticoid receptor, said DNA-binding domain is not derived from a glucocorticoid receptor or an E. coli LexA protein.

9. A method according to claim 8, wherein said modified ecdysone receptor is further characterized as having substantially no constitutive activity in mammalian cells.

10. A method according to claim 9, wherein the DNA-binding domain of said modified ecdysone receptor is derived from a member of the steroid/thyroid hormone superfamily of receptors.

11. A method according to claim 10, wherein said member of the steroid/thyroid hormone superfamily of receptors is selected from: EcR, vitamin D<sub>3</sub> receptor, RAR $\alpha$ , RAR $\beta$ , RAR $\gamma$ , RXR $\alpha$ , RXR $\beta$ , RXR $\gamma$ , TR $\alpha$ , TR $\beta$ , or ER.

12. A method according to claim 11, wherein the DNA-binding domain of the modified ecdysone receptor is characterized as having a P-box amino acid sequence that differs from the P-box amino acid sequence of the naturally  
5 occurring DNA-binding domain.

13. A method according to claim 12, wherein said modified P-box amino acid sequence preferentially binds to a different hormone response element half-site than said naturally occurring P-box amino acid sequence.

14. A method according to claim 13, wherein the DNA-binding domain of said modified ecdysone receptor is derived from EcR and the P-box amino acid sequence is GSCKV (SEQ ID NO:3).

15. A method according to claim 8, wherein said activation domain is obtained from a member of the steroid/thyroid hormone superfamily of receptors.

16. A method according to claim 8, wherein said activation domain is selected from a glucocorticoid receptor activation domain, a VP16 activation domain or a GAL4 activation domain.

17. A method according to claim 1, wherein said modified ecdysone receptor is selected from VpEcR, VgEcR or GEcR.

18. A method according to claim 17, wherein said modified ecdysone receptor is VgEcR having the amino acid sequence set forth in SEQ ID NO:5.

19. A method according to claim 1, wherein said receptor capable of acting as a silent partner is RXR.

20. A method according to claim 19, wherein said RXR is exogenous to said mammalian subject.

21. A method according to claim 1, wherein said exogenous gene is a wild type gene and/or therapeutic gene.

22. A method according to claim 21, wherein said wild type gene is selected from genes which encode products:

5 the substantial absence of which leads to the occurrence of a non-normal state in said subject; or

a substantial excess of which leads to the occurrence of a non-normal state in said subject.

23. A method according to claim 21, wherein said therapeutic gene is selected from those which encode products:

5 which are toxic to the cells in which they are expressed; or

which impart a beneficial property to said subject.

24. A method of inducing the expression of an exogenous gene in a mammalian subject containing:

5 (i) a DNA construct comprising an exogenous gene under the control of an ecdysone response element,

10 (ii) DNA encoding a modified ecdysone receptor under the control of an inducible promoter; wherein said modified ecdysone receptor, in the presence of a ligand therefor, and optionally in the further presence of a receptor capable of acting as a silent partner therefor, binds to said ecdysone response element, and

15 (iii) a ligand for said modified ecdysone receptor;

said method comprising subjecting said subject to conditions suitable to induce expression of said modified ecdysone receptor.

25. A method of inducing expression of an exogenous gene in a mammalian subject containing a DNA construct containing said exogenous gene under the control of an ecdysone response element, said method comprising  
5 introducing into said subject:

a modified ecdysone receptor; and  
a ligand for said modified ecdysone receptor,

wherein said receptor, in combination with a  
10 ligand therefor, and optionally in the further presence of a receptor capable of acting as a silent partner therefor, binds to said ecdysone response element, activating transcription therefrom.

26. A method for the expression of a recombinant product detrimental to a host organism, said method comprising:

transforming suitable host cells with:

5 (i) a DNA construct encoding said recombinant product under the control of an ecdysone response element, and  
(ii) DNA encoding a modified ecdysone receptor;

10 growing said host cells in suitable media; and  
inducing expression of said recombinant product by introducing into said host cells ligand(s) for said modified ecdysone receptor, and optionally a receptor capable of acting as a silent partner for said modified  
15 ecdysone receptor.

27. A modified ecdysone receptor comprising:  
an ecdysone ligand binding domain;  
a DNA-binding domain obtained from a DNA-  
binding protein; and  
5 an activation domain of a transcription  
factor,  
wherein at least one of said DNA-binding  
domain or said activation domain is not obtained  
from a native ecdysone receptor,  
10 with the proviso that when said activation domain is  
derived from a glucocorticoid receptor, said DNA-binding  
domain is not derived from a glucocorticoid receptor or an  
E. coli LexA protein.

28. A nucleic acid encoding a modified ecdysone  
receptor according to claim 27.

29. A homomeric receptor comprising a plurality  
of modified ecdysone receptors according to claim 27.

30. A heterodimeric receptor comprising a  
modified ecdysone receptor according to claim 27, and at  
least one silent partner of the steroid/thyroid superfamily  
of receptors.

31. A heterodimeric receptor according to claim  
30, wherein said silent partner is a mammalian-derived  
receptor.

32. A heterodimeric receptor according to claim  
31, wherein said mammalian-derived receptor is RXR.

33. A modified ecdysone receptor response element comprising, in any order, a first half-site and a second half-site separated by a spacer of 1-5 nucleotides; wherein said first half-site has the  
5 sequence:

-RGBNNM-,

wherein

each R is independently selected from A or G;  
each B is independently selected from G, C, or T;  
10 each N is independently selected from A, T, C, or G; and

each M is independently selected from A or C;  
with the proviso that at least 4 nucleotides of each  
-RGBNNM- group of nucleotides are identical with the  
15 nucleotides at comparable positions of the sequence  
-AGGTCA-; and

said second half-site is obtained from a  
glucocorticoid receptor subfamily response element.

34. A gene transfer vector comprising a transcription regulatory region having a minimal promoter, and a modified ecdysone response element according to claim 33, wherein said regulatory region is operatively associated with DNA containing an exogenous gene, and  
5 wherein said modified ecdysone response element is present in 1 up to about 6 copies.

35. A vector according to claim 34, wherein said regulatory region further comprises a binding site for a ubiquitous transcription factor.

36. A vector according to claim 35, wherein said binding site is positioned between said promoter and said synthetic ecdysone response element.

37. A vector according to claim 36, wherein said ubiquitous transcription factor is Spl.

38. A vector according to claim 34, wherein said promoter is tissue-specific.

39. A recombinant cell containing a nucleic acid encoding a modified ecdysone receptor according to claim 28.

40. A transgenic mammal containing a nucleic acid encoding a modified ecdysone receptor according to claim 28.

41. A method for inducing expression of an exogenous gene in a transgenic mammal according to claim 40, said method comprising:

introducing into said mammal a DNA construct  
5 encoding an exogenous gene under the transcription control of an ecdysone response element responsive to said modified ecdysone receptor; and

10 administering to said mammal an amount of ligand for said modified ecdysone receptor effective to induce expression of said exogenous gene.

42. The method according to claim 41, wherein said modified ecdysone receptor forms a heterodimer with a silent partner of the steroid/thyroid hormone superfamily of receptors.

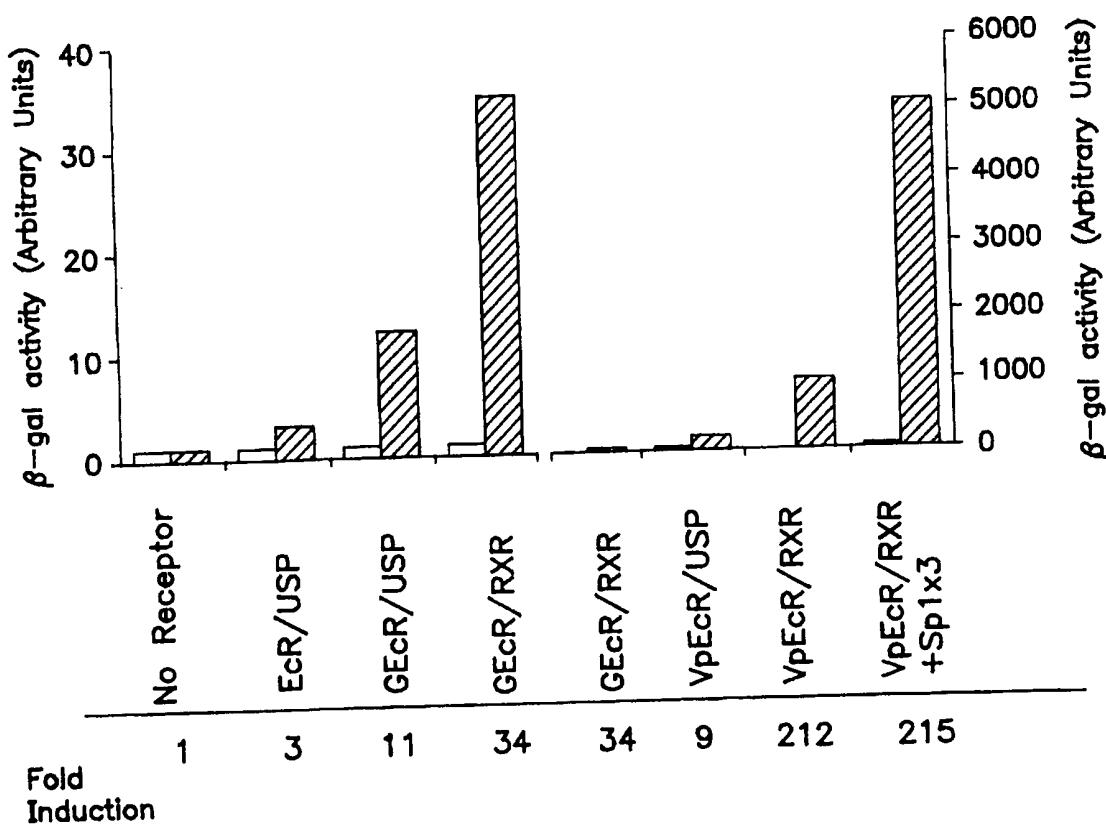


FIG. IA

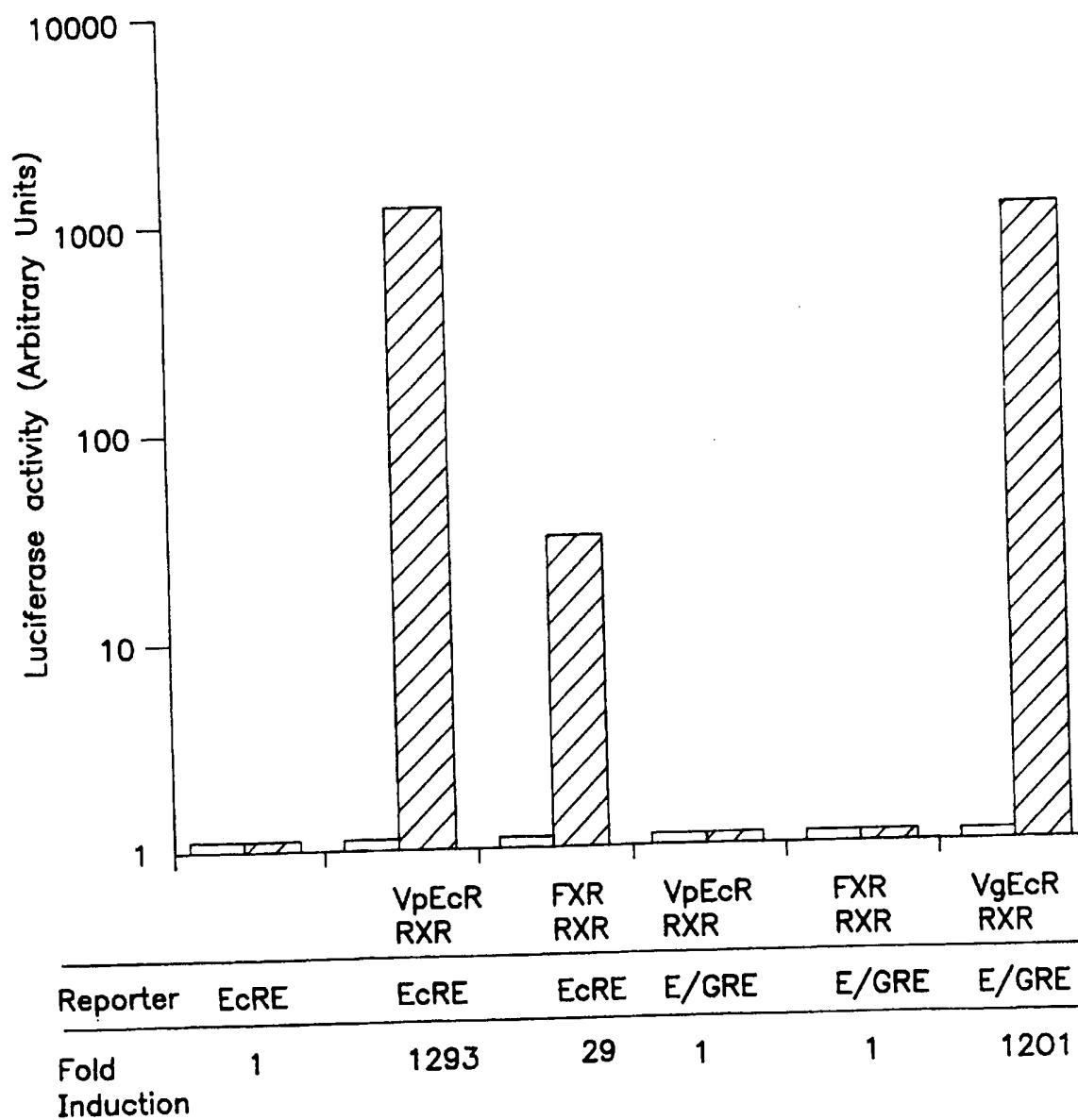


FIG. 1B

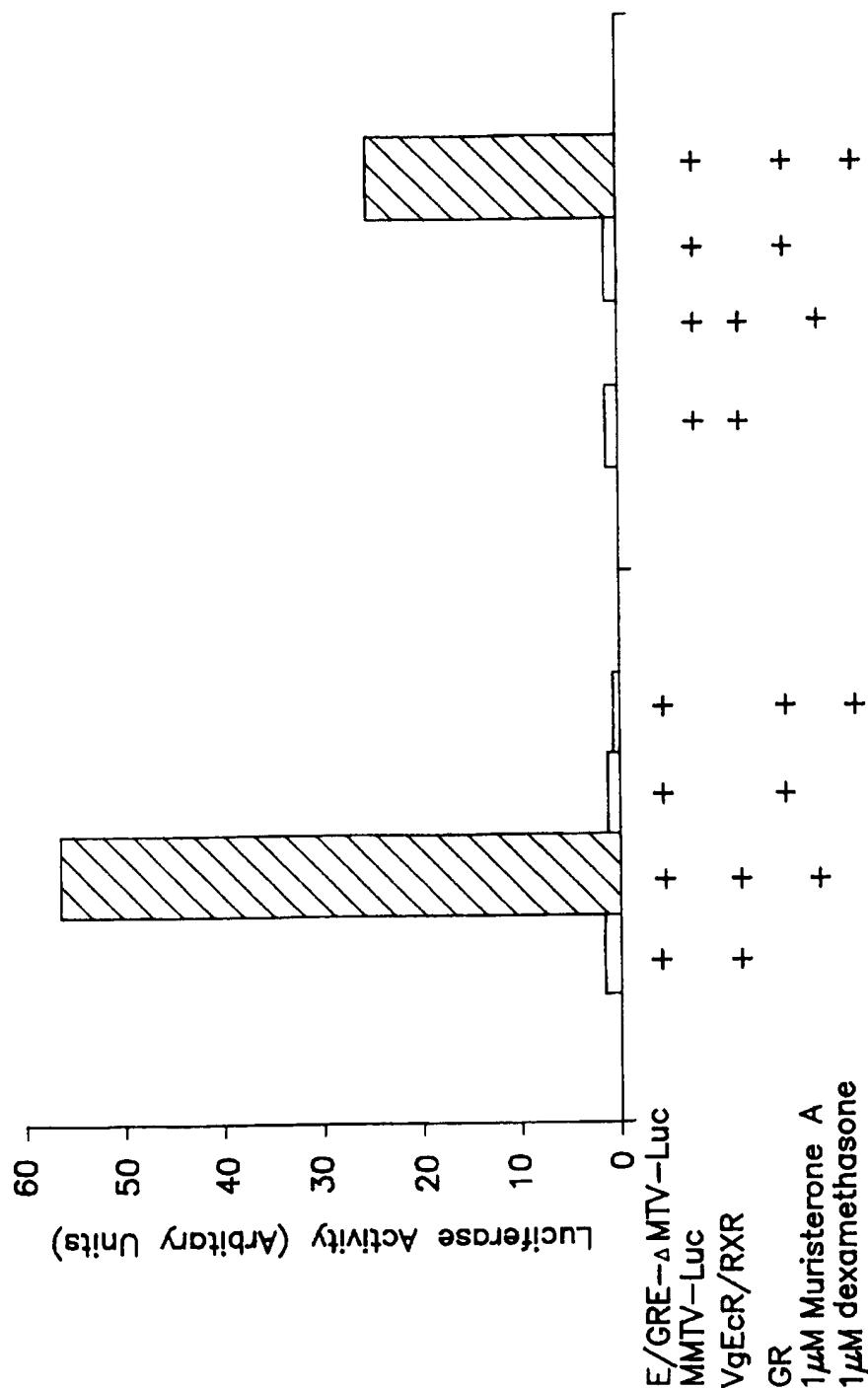
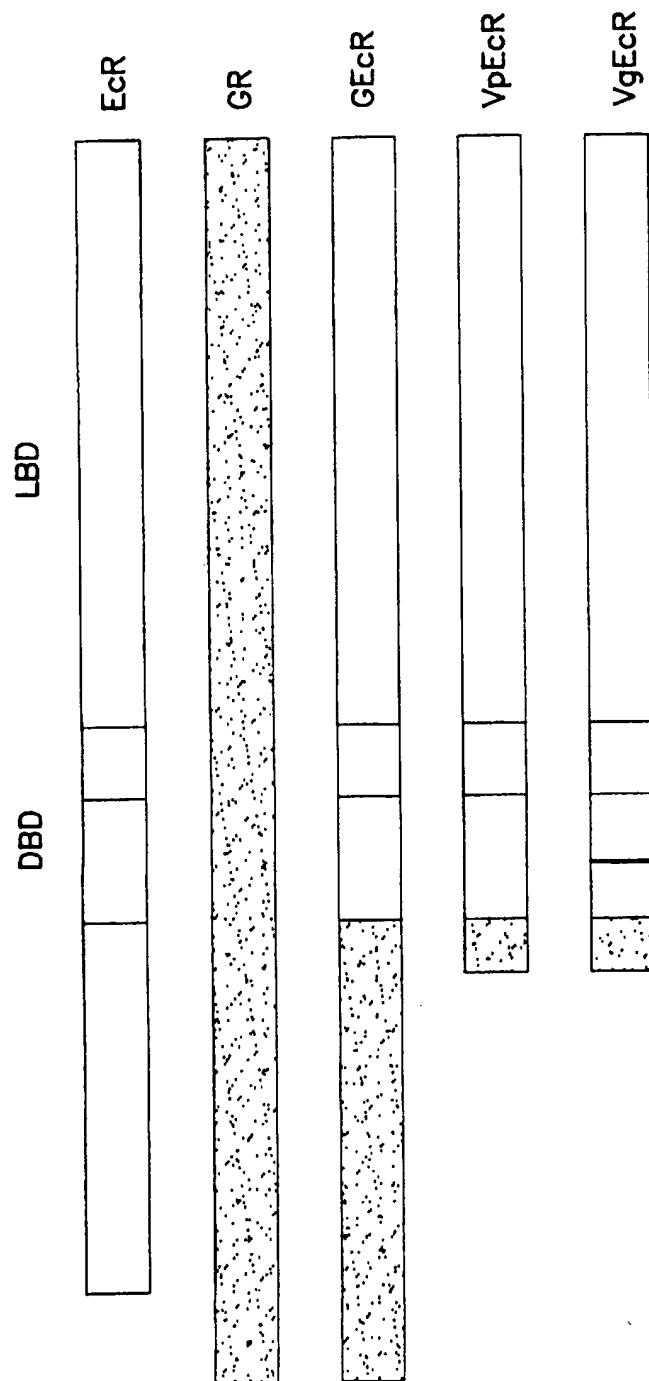


FIG. IC



**FIG. ID**

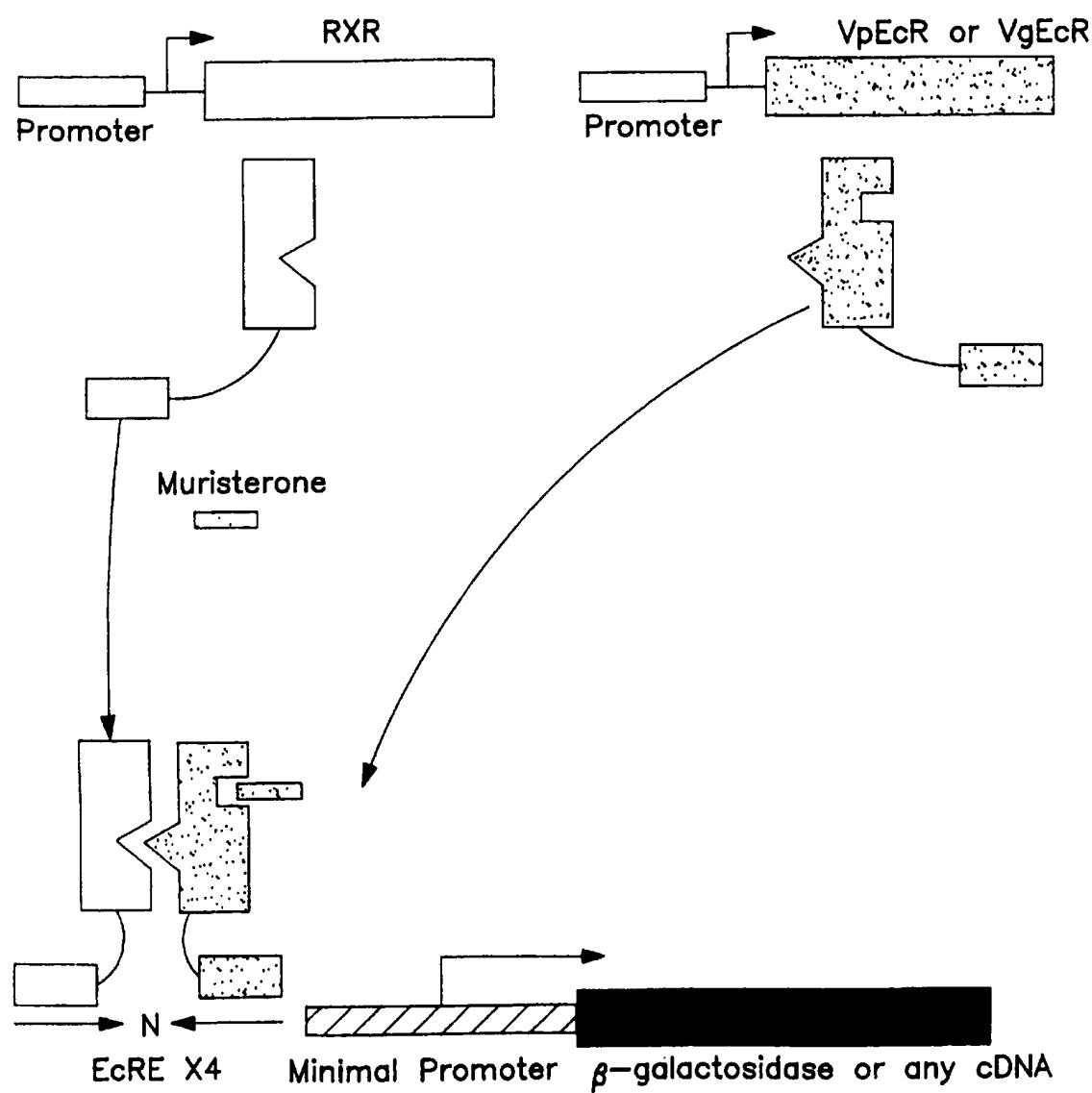


FIG. 2

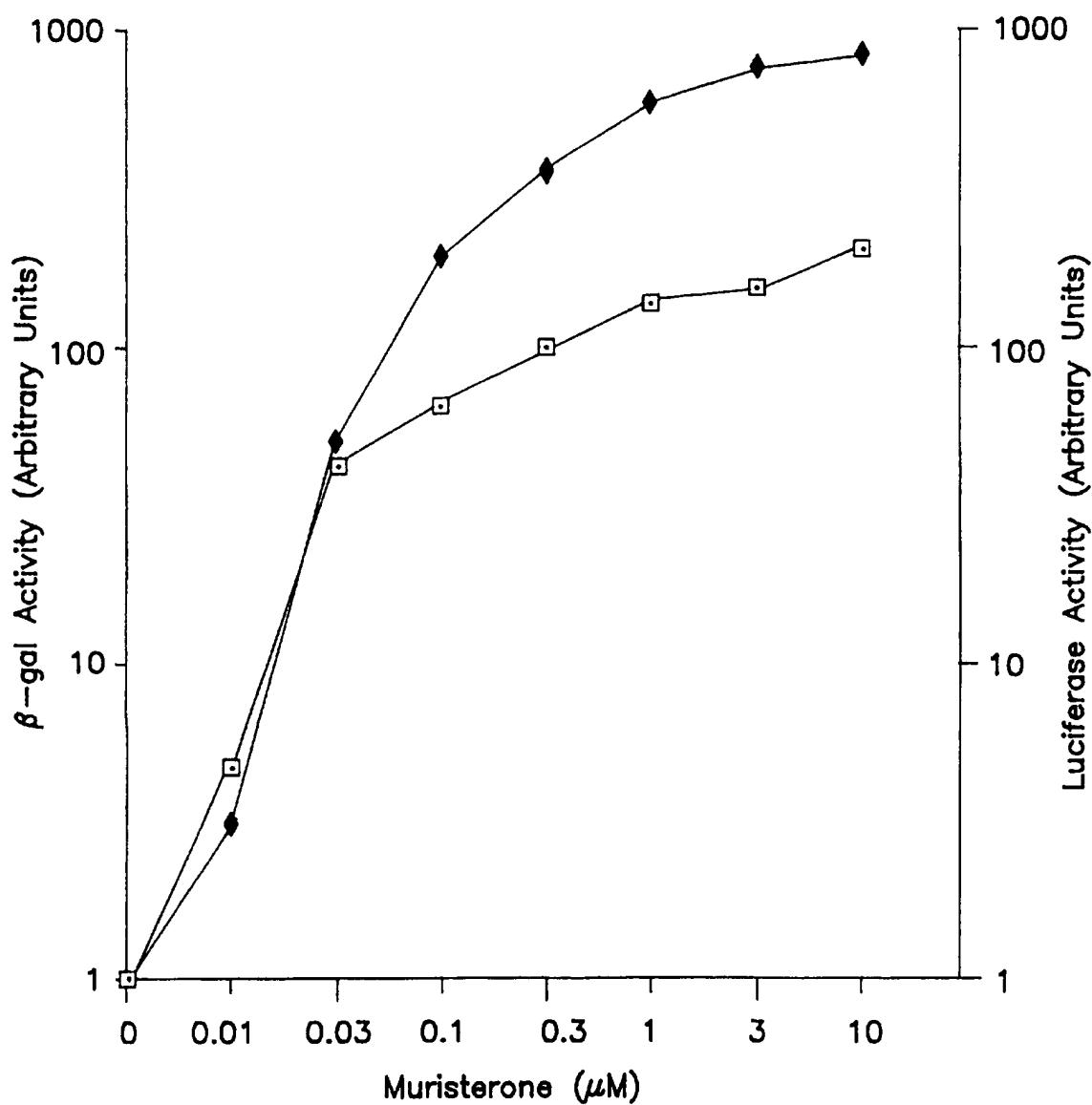


FIG. 3A

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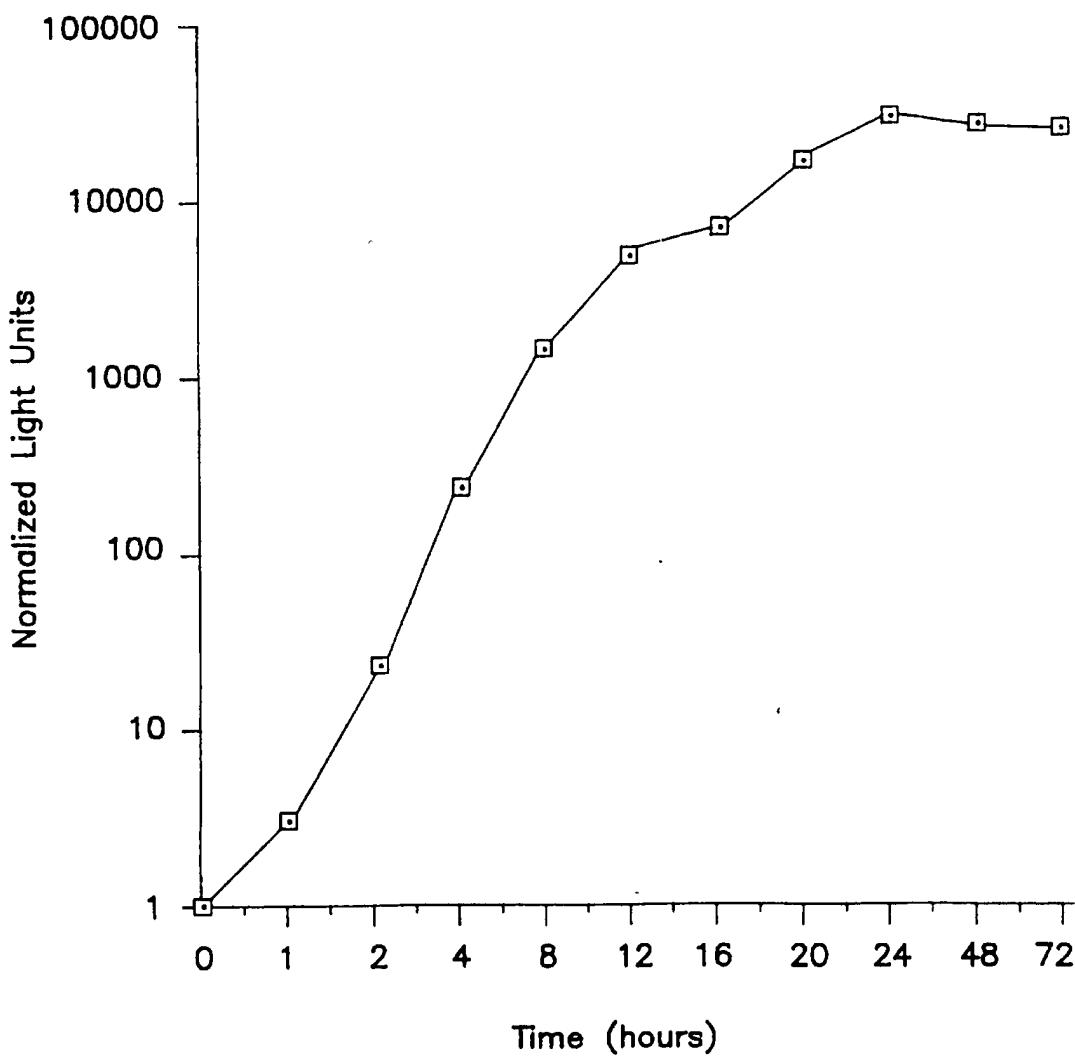


FIG. 3B

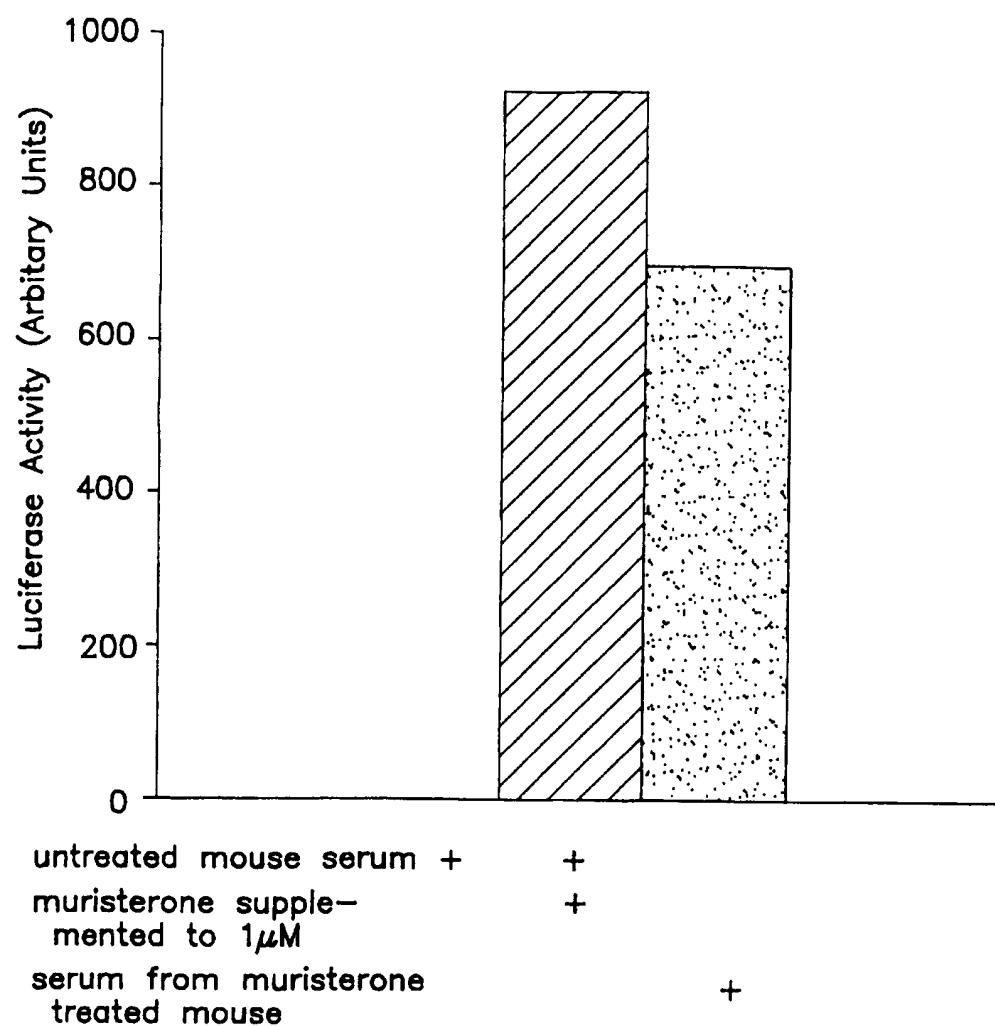


FIG. 4

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 97/05330

A. CLASSIFICATION OF SUBJECT MATTER					
IPC 6	C12N15/85	C12N15/12	C12N5/10	C07K14/72	A01K67/027

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 C12N C07K A01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 91 13167 A (UNIV LELAND STANFORD JUNIOR) 5 September 1991 see the whole document ---	1,21,24, 25
X	CELL, vol. 71, no. 1, 2 October 1992, pages 63-72, XP002036325 YAO T. ET AL.: "Drosophila ultraspiracle modulates ecdysone receptor function via heterodimer formation" cited in the application see the whole document ---	1,17,27, 28,30,39



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

\* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

\*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

\*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

\*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

\*&\* document member of the same patent family

1

Date of the actual completion of the international search

Date of mailing of the international search report

29 July 1997

08.08.97

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Authorized officer

Kania, T

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 97/05330

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 93 03162 A (GENENTECH INC) 18 February 1993	1,17,21, 24,25, 27,28, 39,41,42 8-11,15, 16
A	see the whole document  & PNAS U.S.A., vol. 89, no. 14, 15 July 1992, pages 6314-6318, CHRISTOPHERSON K. ET AL.: "Ecdysteroid-dependent regulation of genes in mammalian cells by a Drosophila ecdysone receptor and chimeric transactivators" see the whole document ---	
X	WO 94 01558 A (SALK INST FOR BIOLOGICAL STUDI) 20 January 1994	1,17, 21-28, 30,39
Y	see the whole document ---	19,20, 31,32
Y	NATURE, vol. 362, 1 April 1993, pages 471-475, XP002036326 THOMAS H. ET AL.: "Heterodimerization of the Drosophila ecdysone receptor with retinoid X receptor and ultraspiracle" see the whole document ---	19,20, 31,32
A	WO 92 16546 A (SALK INST FOR BIOLOGICAL STUDI) 1 October 1992 see the whole document ---	2-7,33, 34,38
A	NATURE, vol. 366, 2 December 1993, pages 476-479, XP002036327 YAO T. ET AL.: "Functional ecdysone receptor is the product of EcR and ultraspiracle genes" cited in the application see the whole document ---	1-42
P,X	PNAS U.S.A., vol. 93, no. 8, 16 April 1996, pages 3346-3351, XP002036328 NO D. ET AL.: "Ecdysone-inducible gene expression in mammalian cells and transgenic mice" see the whole document -----	1-42

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 97/05330

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:  
**Remark:** Although claim(s) 1-26, 41, 42 as far as in vivo methods are concerned is(are) directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound/composition.
2.  Claims Nos.: because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out specifically:
3.  Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

The additional search fees were accompanied by the applicant's protest.  
 No protest accompanied the payment of additional search fees.

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International Application No

PCT/US 97/05330

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9113167 A	05-09-91	AU 1779295 A AU 7492291 A CA 2076386 A EP 0517805 A US 5514578 A	14-09-95 18-09-91 27-08-91 16-12-92 07-05-96
WO 9303162 A	18-02-93	EP 0598011 A JP 7501928 T	25-05-94 02-03-95
WO 9401558 A	20-01-94	AU 4769793 A CA 2137462 A JP 8501211 T	31-01-94 20-01-94 13-02-96
WO 9216546 A	01-10-92	AU 668683 B AU 1657892 A CA 2100584 A EP 0576590 A JP 6508509 T	16-05-96 21-10-92 20-09-92 05-01-94 29-09-94